DISSERTATION FROM THE
NORWEGIAN SCHOOL OF
SPORT SCIENCES
**2017**

Anders Aandstad

# Physical Fitness and Physical Activity in Norwegian Home Guard Soldiers

A cross-sectional and method comparison study

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# I Sammendrag på norsk [summary in Norwegian]

**INNLEDNING:** Fysisk form er en viktig egenskap hos soldater, ettersom militært arbeid kan være fysisk krevende. For å forsikre oss om at soldater er «klar til strid» blir soldater selektert og testet på fysisk form, og fysisk trening og fysisk aktivitet vektlegges for å vedlikeholde eller øke den fysiske kapasiteten. Eksisterende forskningslitteratur har primært beskrevet fysisk form og fysisk aktivitet hos heltidssoldater, mens reservesoldater i mindre grad er studert. Ingen tidligere studier har beskrevet fysisk form og aktivitet hos soldater i det norske Heimevernet (HV). For best mulig beskrivelse av fysisk form og aktivitet er det viktig at målemetodenes validitet og reliabilitet er kjent – og helst da spesifikt for populasjonen som undersøkes. Noen av disse målemetodene er ikke tilstrekkelig validert på militært personell, og denne type metodestudier er derfor nødvendige.

**MÅL:** Hovedmålsettingen med denne avhandlingen er å beskrive fysisk form og fysisk aktivitet i et representativt utvalg av norske HV-soldater. En annen hensikt er å undersøke validitet og reliabilitet for to viktige målemetoder benyttet i HV-studien; *20 meter shuttle run test* (20 m SRT) for måling av aerob kapasitet, og bioelektrisk impedans analyse (BIA) for estimering av kroppsfett.

**METODE:** Denne avhandlingen bygger på tre delstudier: en metodestudie av 20 m SRT, en metode-studie av ulike feltmetoder for måling av kroppssammensetning, og en tverrsnittsstudie av fysisk form og fysisk aktivitet hos HV-soldater. Metodestudien av 20 m SRT ble utført i to faser. I fase én ble test–retest reliabilitet undersøkt hos 38 mannlige HV-soldater. I tillegg ble det utviklet en ny prediksjonsligning for maksimalt oksygenopptak ($\dot{V}O_{2maks}$), basert på sammenhengen mellom prestasjon ved 20 m SRT og direkte målt $\dot{V}O_{2maks}$. I fase to ble vår nye prediksjonsligning, samt fem eksisterende ligninger, kryssvalidert på 28 mannlige kadetter. Metodestudien vedrørende måling av kroppssammensetning bestod av test–retest reliabilitetsanalyser for fettprosent målt gjennom hudfoldsmålinger, enkelt- og multi-frekvens BIA, samt kombinasjon av enkelt-frekvens BIA med hudfoldsmåling. Validiteten av disse feltmetodene, sammen med bruk av ulike eksisterende prediksjonsligninger, ble vurdert gjennom sammenligning opp dobbelt radioabsorpsjonsmetri (DXA). Seksti-fem mannlige- og kvinnelige kadetter, soldater og offiserer var inkludert i denne delstudien. Tverrsnittsstudien av fysisk form og fysisk aktivitet i HV ble gjennomført på 799 mannlige HV-soldater fra fem HV-distrikter og totalt 38 tropper. Aerob kapasitet, kroppssammensetning og antropometri ble målt under HV-øvelse. Fysisk aktivitet ble målt objektivt gjennom SenseWear Armband monitorer påsatt under HV-øvelse og under sivilt liv påfølgende uke. Enkelte soldater gjennomførte ikke alle de ulike målingene og testene – for eksempel er kun 299 soldater inkludert i analysene av fysisk aktivitet under HV-øvelse.

**RESULTATER:** Analysene av test–retest reliabilitet for 20 m SRT viste en intraklasse-korrelasjon (ICC) på 0,95 (0,90, 0,97) og en *95 % limits of agreement* (LoA) på ± 3.1 $mL·kg^{-1}·min^{-1}$. Pearson korrelasjon mellom estimert $\dot{V}O_{2maks}$ fra 20 m SRT og direkte målt $\dot{V}O_{2maks}$ var *r* = 0,82 for HV-soldater og *r* = 0,69 for kadetter. Tilsvarende LoA var henholdsvis ± 7.2 og ± 6.2 $mL·kg^{-1}·min^{-1}$. Det ble påvist opptil 23 % forskjell i estimert $\dot{V}O_{2maks}$ da ulike eksisterende prediksjonsligninger ble sammenlignet. Test–retest ICC for estimert fettprosent var i de fleste tilfeller ≥ 0,95 for både hudfoldsmålinger og BIA, mens test–retest LoA vanligvis var mellom ± 1–3 prosentpoeng kroppsfett. Estimert fettprosent målt gjennom hudfoldsmålinger og BIA korrelerte vanligvis opp mot DXA med en Pearson *r* ≈ 0,80–0,90. Tilsvarende varierte LoA fra 3,5–8,0 prosentpoeng kroppsfett, avhengig av type feltmetode, prediksjonsligning og kjønn. I gjennomsnitt presterte norske HV-soldater å løpe 70 lengder (*shuttles*) under 20 m SRT, noe som tilsvarer et $\dot{V}O_{2maks}$ på cirka 50 $mL·kg^{-1}·min^{-1}$. Gjennomsnittlig kropps-masseindeks, mageomkrets og fettprosent var henholdsvis 26,1 $kg·m^{-2}$, 94,0 cm and 19,7 %. Det var små- eller ingen forskjeller i både antropometri og aerob kapasitet mellom HVs innsatsstyrke og forsterkningsstyrke, samt mellom menige og befal. Med tanke på fysisk aktivitet i sivilt liv nådde 44 % av HV soldatene anbefalingen om 10.000 steg om dagen. Under sivilt liv oppnådde HV-soldatene 4 minutter (median verdi) med daglig fysisk aktivitet av svært høy intensitet (> 9 MET). HV-soldatene var mer moderat fysisk aktive under HV-øvelse sammenlignet med i sitt sivile liv. Samtidig hadde de færre minutter med høy–svært høy intensitet under HV-øvelse, sammenlignet med sivilt liv.

**KONKLUSJON:** 20 m SRT virker å være en tilstrekkelig reliabel test for praktisk bruk i Forsvaret. Når det gjelder validitet så kan 20 m SRT estimere $\dot{V}O_{2maks}$ nøyaktig på gruppenivå, men det må tas høyde for en relativt stor feilmargin på individnivå. Ingen av feltmetodene for måling av kropps-sammensetning var klart bedre enn de andre feltmetodene med tanke på reliabilitet og validitet. Mange av prediksjonsligningene for fettprosent virker å være reliable for praktisk bruk i Forsvaret. Validiteten tilsier imidlertid at en må regne med en relativt stor feilmargin ved estimering av fettprosent på individnivå. I tillegg varierte reliabilitet og validitet mye mellom enkelte av prediksjonsligningene. To av tre HV-soldater tilfredsstilte generelle anbefalinger hva gjelder aerob kapasitet, kroppssammensetning og antropometri. Disse generelle anbefalingene er imidlertid ikke nødvendigvis gyldige for HV-soldater. Lite fysisk aktivitet med høy intensitet under HV-øvelsene indikerer at arbeidsoppgavene i HV er relativt lite kondisjonskrevende. Flertallet av HV-soldater ser derfor ut til å ha tilstrekkelig god fysisk form til å utføre planlagte HV-oppdrag. Det kan likevel være verdifullt å øke fokus på fysisk form og fysisk aktivitet i HV. Dette vil kunne gjøre HV-soldatene mer fleksible og bedre rustet til å utføre andre og mer fysisk krevende tjenesteoppdrag som måtte oppstå.

## II Summary

**INTRODUCTION:** Physical fitness is an important attribute in soldiers because military work may be physically demanding. To ensure that military personnel are "fit to fight", soldiers are typically selected and evaluated based on fitness tests, and physical training and physical activity are emphasized to maintain or develop physical fitness. Existing literature has primarily described fitness and activity levels in full-time soldiers, while reserve soldiers are less frequently investigated. No previous studies have reported physical fitness or physical activity levels in the Norwegian Home Guard (HG) force. When describing fitness and activity levels, it is important that the validity and reliability of the measurement tools are known, preferably for the population of interest. Some of the frequently used methods have not been sufficiently evaluated for validity and reliability in military populations, and such studies are therefore needed.

**AIMS:** The main aim of this thesis is to describe physical fitness and physical activity in a nationally representative sample of Norwegian HG soldiers. An additional aim is to investigate the validity and reliability of two primary outcome measures from the HG study: the 20 meter shuttle run test (20 m SRT) for aerobic fitness and a bioelectrical impedance analysis (BIA) method for body fat estimations.

**METHODS:** This thesis is comprised of three studies: a method comparison study of the 20 m SRT, a method comparison study of body composition field methods, and a cross-sectional study of physical fitness and physical activity in HG soldiers. The method comparison study of the 20 m SRT was conducted in two stages. Stage one included 38 male HG soldiers and consisted of test–retest reliability analysis, as well as generation of a new maximal oxygen uptake ($\dot{V}O_{2max}$) prediction equation based on a comparison between 20 m SRT performance and directly measured $\dot{V}O_{2max}$. In stage two, our new 20 m SRT equation and five alternative existing equations were cross-validated on 28 male cadets. The method comparison study of body composition field methods included test–retest reliability analysis of percent body fat estimated from skinfolds, single frequency and multi-frequency BIA, and a combined skinfold and single frequency BIA method. Validity of these field methods, using several body fat prediction equations, was evaluated against dual-energy X-ray absorptiometry (DXA). Sixty-five male and female cadets, soldiers and officers were included in this study. The cross-sectional study on physical fitness and physical activity in HG soldiers was conducted on 799 male HG soldiers from five HG districts and 38 troops. Aerobic capacity, body composition and anthropometrics were measured during HG military training. Physical activity was objectively measured with the SenseWear Armband monitor during HG military training and the succeeding civilian week. Some soldiers did not carry out all measurements; for example, only 299 soldiers were included in the analysis of physical activity during HG training.

**RESULTS:** The 20 m SRT produced a test–retest reliability intraclass correlation coefficient (ICC) of 0.95 (0.90, 0.97) and a 95 % limits of agreement (LoA) of ± 3.1 $mL·kg^{-1}·min^{-1}$. Pearson correlation between estimated $\dot{V}O_{2max}$ from the 20 m SRT and directly measured $\dot{V}O_{2max}$ was $r$ = 0.82 and $r$ = 0.69 in HG soldiers and cadets, respectively. The corresponding LoA were ± 7.2 and ± 6.2 $mL·kg^{-1}·min^{-1}$, respectively. A discrepancy of up to 23 % for mean estimated $\dot{V}O_{2max}$ was demonstrated among previously published 20 m SRT equations. Test–retest ICC for estimated percent body fat from skinfold and BIA was typically ≥ 0.95, while test–retest LoA were normally between ± 1–3 body fat percentage points. Estimated percent body fat from skinfold and BIA typically correlated to DXA with a Pearson $r$ ≈ 0.80–0.90. The LoA varied from 3.5–8.0 body fat percentage points, dependent on method, equation, and gender. Mean 20 m SRT run performance in Norwegian HG soldiers was 70 shuttles, which corresponds to a $\dot{V}O_{2max}$ of approximately 50 $mL·kg^{-1}·min^{-1}$. Mean body mass index, waist circumference and body fat were 26.1 $kg·m^{-2}$, 94.0 cm and 19.7 %, respectively. Differences in anthropometrics and aerobic fitness related to type of HG force or military rank were generally small or nonexistent. In terms of physical activity, the commonly recommended 10,000 steps per day were reached by 44 % of the soldiers during civilian life. The median time spent in ≥ very vigorous intensity physical activity (> 9 metabolic equivalents) was 4 minutes per day during civilian life. The HG soldiers spent significantly more time in moderate intensity physical activity during HG training compared to civilian life, but less time in vigorous and very vigorous physical activity.

**CONCLUSIONS:** The 20 m SRT appears to be a sufficiently reliable test for practical use in the military. In terms of validity, the 20 m SRT may estimate $\dot{V}O_{2max}$ accurately on group level, but a relatively large measurement error should be accounted for at the individual level. No single body composition field method stood out as clearly more reliable and valid than the other methods. Many equations seem reliable for general use in the military – yet, a relatively large measurement error must be accounted for at the individual level when predicting percent body fat. Moreover, reliability and validity varied substantially among some of the body composition equations. Two out of three HG soldiers reached commonly recommended values for aerobic fitness, body composition and anthropometrics. However, such general fitness recommendations may not necessarily be valid for HG soldiers. The low volume of high intensity physical activity during HG training indicates relatively low aerobic demands during HG military service. Thus, the majority of the HG soldiers seem to have a sufficient physical capacity to carry out the pre-planned jobs designated for HG soldiers. Increased focus on physical fitness and physical activity could still be valuable to physically prepare HG soldiers for more unforeseen tasks with possibly higher demands than observed during HG training.

## III Acknowledgements

A long-lasting work and journey is about to end. I don't really know when my PhD project started; it merely developed into a PhD over the years. What I *do* know is that many people have contributed along the way. Some of you have helped me along the main path leading to this thesis, while others have contributed on inspiring scientific detours. I want to express my sincere appreciation to all institutions and people who have made this work possible.

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## IV List of papers

**I**. Aandstad A, Holme I, Berntsen S, Anderssen SA. Validity and Reliability of the 20 Meter Shuttle Run Test in Military Personnel. *Military Medicine* 2011; 176 (5): 513–518.

**II**. Aandstad A, Holtberget K, Hageberg R, Holme I, Anderssen SA. Validity and Reliability of Bioelectrical Impedance Analysis and Skinfold Thickness in Predicting Body Fat in Military Personnel. *Military Medicine* 2014; 179(2): 208–217.

**III**. Aandstad A, Hageberg R, Holme I, Anderssen SA. Anthropometrics, Body Composition, And Aerobic Fitness in Norwegian Home Guard Personnel. *The Journal of Strength and Conditioning Research* 2014; 28(11): 3206–3214.

**IV**. Aandstad A, Hageberg R, Holme I, Anderssen SA. Objectively Measured Physical Activity in Home Guard Soldiers During Military Service and Civilian Life. *Military Medicine* 2016; 181(7): 693–700

## V Abbreviations

| | |
|---|---|
| 20 m SRT | 20 meter shuttle run test |
| BD | Body density |
| BF | Body fat |
| BIA | Bioelectrical impedance analysis |
| CI | Confidence interval |
| CV | Coefficient of variation |
| DLW | Doubly labelled water |
| DXA | Dual-energy X-ray absorptiometry |
| FFM | Fat free mass |
| HG | Home Guard |
| HR | Heart rate |
| ICC | Intraclass correlation coefficient |
| $km \cdot h^{-1}$ | Kilometer per hour |
| LHL | Last half level |
| $L \cdot min^{-1}$ | Liters per minute |
| LoA | Limits of agreement |
| MET | Metabolic equivalent |
| MF | Multi-frequency |
| $mL \cdot kg^{-1} \cdot kg^{-1}$ | Milliliters per minute per kilogram bodyweight |
| $mmol \cdot L^{-1}$ | Millimoles per liter |
| PA | Physical activity |
| RAP | Rapid Reaction |
| REG | Regular |
| SD | Standard deviation |
| SF | Single frequency |
| SKF | Skinfold |
| TEE | Total energy expenditure |
| $\dot{V}O_2$ | Oxygen uptake |
| $\dot{V}O_{2max}$ | Maximal oxygen uptake |
| $\dot{V}O_{2peak}$ | Peak oxygen uptake |

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# 1 INTRODUCTION

Throughout history, militaries have repeatedly stressed the importance of physical capacity in soldiers.[1] In Ancient Greece, Lukian (born 120 A.D.) emphasized the significance of physical training for soldiers to meet battlefield demands.[2] Casualty evacuation was one of the occupational tasks that Lukian mentioned as an important soldiering skill. The long marches of Roman legionnaires are also well described in the literature.[3] Whipp et al.[4] claim that a minimum requirement for legionnaires was to march 30 miles within five Roman summer hours (speed approximately 4.6 $km \cdot h^{-1}$), with a load of about 20 kg. Later, the knights of the Middle Ages wore body armors with weights of approximately 20–30 kg,[3] which must have made movements physically strenuous.

The abovementioned tasks like casualty evacuation, loaded marching and carrying external weight are still relevant physical demands for soldiers today.[5] However, modern soldiers have access to motorized transportation, in addition to equipment and technology that may reduce physical stress. Moreover, military forces today are more specialized, and job related physical demands vary significantly among different branches, units, specialties and missions.[6] Some soldiers rarely experience physically demanding job tasks,[7] while others frequently need a high physical capacity to carry out their duties in a safe and efficient way. Overall, it is claimed that the physical demands placed on modern soldiers continue to be substantial.[8]

Since many soldiers are still faced with physically challenging work during service (high physical demands), the military usually emphasizes both physical training and the evaluation of physical capacity through fitness tests.[9] The link between these and some other related concepts are summarized in Figure 1. The main concepts in this figure are explained briefly below.

**Physical demands** relates to the amount of physical effort a task or service requires. The occupational physical demands are the basis for focusing on physical training and testing in the military. If military service no longer encompassed physically demanding work, the rationale for physical training and selection based on physical fitness would diminish. It could be argued that health, appearance, military identity, tradition, etc. are other valid reasons for emphasizing physical training and testing in armed forces. However, such arguments alone are probably not sufficient to justify selection based on fitness, nor the allocation of time and effort on physical training.

An analysis of a job's physical demands includes a description and quantification of the aspects of physical fitness or physical performance required to execute the actual job.[1] Such an analysis can be divided into two parts: the task analysis and the demand analysis.[1, 10] The task analysis includes identifying the relevant activities that are physically demanding in specific trades, while the demand analysis relates to frequency, duration, intensity, etc. of the identified activity. The demand analysis can also include a description of the fitness level required to carry out the job (e.g. $\dot{V}O_{2max}$).[1] To establish the exact physical demands of a military trade is difficult, as unforeseen aspects of warfare make such analysis inherently imprecise.

The task and demand analyses should influence the choice of **physical fitness tests** used. If a group of soldiers typically walks long distances, an aerobic fitness test which engages the legs seems reasonable. If the soldiers primarily lift heavy objects, then a maximal strength test with external weight should be relevant. Fitness tests in the military may be divided into physical ability tests and work sample tests.[1] Both types have strengths and weaknesses. Validity, reliability, responsiveness (sensitivity/specificity) and practical aspects play into account when selecting a test or several tests (a test battery) for use in a military setting.[10, 11]

When it is documented that a specific military service includes physically demanding job tasks, and type of fitness tests are established, then **minimum standards** (or requirements) are defined for the trade. Minimum standards are usually expressed directly in a unit related to the fitness test, such as time to run a specified distance, or kilograms lifted. The level of the minimum standards should ideally match the physical demands for the trade. If the minimum standards are set too high, there is a risk of increased number of false negative results, i.e. soldiers fail the test but would have been capable of doing the job. If the minimum standards are set too low, the risk of false positive outcomes increases, that is soldiers pass the test but eventually fail in carrying out the job.[1, 10] Minimum standards determined with reference to the physical requirements of the job are called criterion-referenced standards. If the standards are determined with reference to the distribution of test performances in a relevant population, they are called norm-referenced standards.[10]

The physical fitness tests are used to evaluate the **fitness level** of individuals and groups of soldiers. Physical fitness has broadly been defined as a set of attributes that people have or achieve that relates to the ability to perform physical activity.[12] A more military relevant definition of physical fitness was proposed by the US Department of Defence: “the ability of Service members to meet the physical demands of their jobs for an extended period of time and to have the additional ability of meeting physical emergencies, such as those imposed during combat or other stressful situations”.[1] Physical fitness may include several components, but aerobic capacity, muscular strength/power/-endurance and body composition are among the components most frequently evaluated in military personnel.[1, 13]

Prospective soldiers with fitness levels below the minimum standard might be excluded from military service, or they might be given a chance to reach the necessary level after a period of relevant **physical training.** Physical training (or exercise) can be viewed as a subcategory for physical activity. Physical activity is typically defined as any bodily movement (or action) produced by skeletal muscles that results in energy expenditure,[12, 14] while physical training also includes that the intention of the movement/action is to maintain or increase physical fitness. Physical training is not only important for those who do not pass a test. It will also prepare soldiers for new job assignments where a higher fitness level is required. In addition, a fitness level well above the minimum requirement could be beneficial not only for the individual soldier but also for the unit. Thus, physical training is usually emphasized also for soldiers who are already fit and well above the minimum standards.

This thesis explores physical fitness and physical activity levels in Norwegian HG soldiers, and how to measure relevant physical fitness components in soldiers. The following chapters introduce what is already known about fitness and activity levels in soldiers in general, and reservists (including HG soldiers) in particular. Existing knowledge on how to measure physical fitness and activity is also presented. Occupational physical demands are the source for why physical fitness, physical activity and physical training are of interest to study in soldiers. Hence, this thesis starts with a brief review of the physical tasks and demands faced by modern soldiers.

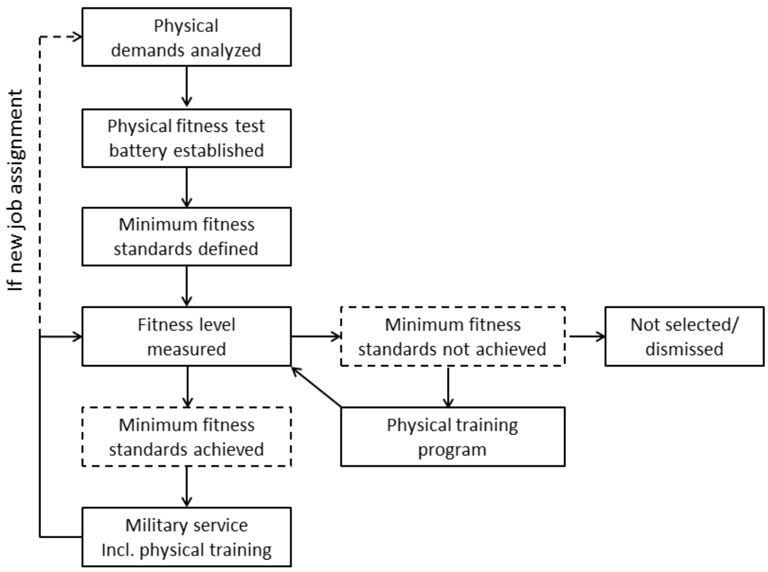


**Figure 1**. Illustration of possible relationships among occupational physical demands, physical tests, minimum fitness standards, measured fitness level and physical training for military units and individual soldiers.

## 1.1 Occupational physical demands in soldiers

Studies on physical demands in operational environments were recently rated as the top priority among military performance researchers, indicating a gap in knowledge in this scientific area.[15] Still, comprehensive reports of physical demands in Canadian,[16, 17] US[18-20] and UK[21-23] forces have been published over the last three decades. For example, Myers et al.[19] identified almost 2000 different physical tasks conducted by US Army soldiers. These reports and other international literature on physical demands in soldiers were summarized by NATO in 2009.[5] The NATO group concluded that the most common physically demanding tasks in their military forces involved 1) manual material handling, 2) loaded marching, and 3) digging.

### 1.1.1 Manual material handling

Manual material handling (i.e. lifting and carrying) is reported to be a very common physically demanding task in the military. In fact, manual material handling was ranked the most frequent physical task in the Canadian, US and UK armies.[5] In a recent study conducted among 1011 Norwegian officers and enlisted personnel from all military branches, lifting heavy objects was also reported as the most frequent physically challenging task.[7] Some examples of typical lifting and carrying tasks in the military include casualty evacuation, moving sand bags, loading trucks, loading shells, carrying jerry cans with fuel, moving bushes and trees, handling food rations and moving and assembling mobile camps.[5, 16, 24-26]

Manual material handling tasks can tax different energy systems depending on the intensity and duration of the work. The ability to lift lighter objects for a prolonged period of time is usually restricted by the soldiers' aerobic capacity.[16] The ability to lift a heavy object once, or to lift and or carry heavy objects for a short period of time depends on the muscular strength or the anaerobic capacity.[5, 27] The physical demands of lifting and carrying depend on several factors, such as the weight and shape of the object, lifting height, carrying distance and moving speed, frequency of the lifts and lifting technique.[28] The oxygen uptake ($\dot{V}O_2$) varies from 0.4 to 3.4 $L \cdot min^{-1}$ in typical repetitive lifting and carrying tasks in the military.[5] For instance, loading shells for a Howitzer cannon requires a $\dot{V}O_2$ of ≥ 1.5 $L \cdot min^{-1}$.[25, 29] Thus, to be able to perform such a job for a prolonged time, a $\dot{V}O_{2max}$ of 3–3.5 $L \cdot min^{-1}$ (43–50 $mL \cdot kg^{-1} \cdot min^{-1}$ for a 70 kg soldier) has been recommended to avoid acute fatigue.[25] However, this recommendation should be viewed as a guideline only, since necessary frequency, duration, weight of loads etc. will vary under different situations.

### 1.1.2 Loaded marching

Loaded marching is another common physically demanding activity in the military. Although long travels are now usually by motorized transportation, movement by foot with backpack and other heavy equipment carriage is still common, especially among army infantry soldiers. In a previous study, 40 % of Norwegian Army officers and enlisted soldiers reported undertaking loaded marching with heavy weight at least once a month.[7] In other military branches, loaded marching was reported to be rare. Although soldiers move shorter distances by foot today than previously, the carried weight appears to have increased. While an infantry soldier carried around 15 kg in military operations before 1900, the weight carried by modern American infantry soldiers has now at least doubled, and may reach up to 70 kg. [5, 30, 31]

Loaded marching may challenge soldiers' aerobic and strength related fitness. When the load is high, maximal strength may be as much of a limiting factor for the performance as aerobic fitness.[32-34] However, it seems most common to describe physical demands from loaded marching in terms of aerobic energy requirements (e.g. $\dot{V}O_2$, kcal, etc.).[5, 35] The energy cost of walking with external weight may be calculated by various prediction equations.[36-38] Several factors determine the energy expenditure of foot marches, such as the soldiers' body mass, load carried, marching speed, terrain and load placement.[30] A daily energy expenditure of 4500–6300 kcal is typically reported among male soldiers during military training that includes foot marching with external load.[39-42] According to NATO,[25] loaded marching requires a $\dot{V}O_{2max}$ of at least 3–3.5 $L{\cdot}min^{-1}$ (43–50 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$). As mentioned for the manual material handling tasks, such defined minimum requirements are not valid in all circumstances. For instance, energy expenditure may increase by 50 % during loaded marching on uneven or hilly terrain, or with heavier loads carried. Aerobic capacity and muscular strength are not the only limiting factors during prolonged loaded marching. Pain, as well as foot, leg, and back problems, may also restrict performance.[18, 43]

### 1.1.3 Digging

NATO defined digging as a separate physically demanding military activity.[5] Digging is included in activities like building trenches, placing explosives in the ground, shoveling snow or sand, and filling sandbags. In a study by Stornæs et al.,[7] about 30 % of Norwegian Army officers and soldiers reported digging activities at least once a month. Yet, more than 90 % of personnel from the other Norwegian military branches reported that digging was not performed in their service. Nevertheless, although digging is not a common activity for all soldiers, it may be viewed as a critical task within the basic military role.[5]

The energy cost of digging varies related to frequency of digging, type and weight of material, type and shape of the digging implement, throwing height and distance, technique, etc.[5] Since shoveling coal has been an historically important task in industry, studies as early as the 1920s have reported directly measured $\dot{V}O_2$ values during shoveling.[44] A review of such studies indicated an aerobic demand of 1–2 $L\cdot min^{-1}$ during this type of work.[5] Several military studies on digging and shoveling have also been conducted, with reported $\dot{V}O_2$ demands of 23–31 $mL\cdot kg^{-1}\cdot min^{-1}$.[5, 16, 45]

The reviewed literature demonstrates that military tasks like manual material handling, loaded marching and digging require $\dot{V}O_2$ values at 1–2 $L\cdot min^{-1}$ (or 15–30 $mL\cdot kg^{-1}\cdot min^{-1}$). At a first glance, such $\dot{V}O_2$ requirements may not appear physically demanding. Yet, to be able to work a full day, submaximal work intensity should not exceed about 40 % of an individual's $\dot{V}O_{2max}$.[46] Accordingly, such prolonged work may require $\dot{V}O_{2max}$ values up to about 5 $L\cdot min^{-1}$ (or 70 $mL\cdot kg^{-1}\cdot min^{-1}$). It must also be emphasized that work intensity (in percent) should be calculated from peak oxygen uptake[a] ($\dot{V}O_{2peak}$) in the actual activity, since activities like marching, carrying and digging typically produce lower $\dot{V}O_{2peak}$ values than values measured during treadmill running.[47, 48] Thus, an isolated sub-maximal $\dot{V}O_2$ value does not necessarily reflect how physically demanding a job task is.

It should also be noted that physical demands may shift due to external factors, or that external factors may inhibit physical performance (increasing the relative physical demand). Thus, factors such as altitude, climate, temperature, nutrition, clothing and sleep may further increase the physical strain compared to what is measured during more optimal settings.[5, 25]

The abovementioned physical demands apply to soldiers in general. Accordingly, we may anticipate that these physical demands also relate to reserve soldiers, although limited research on this topic has been carried out specifically for reserve soldiers.[26, 49] No previous studies on physical demands in Norwegian HG soldiers have been identified.

[a] $\dot{V}O_{2peak}$ is often used instead of $\dot{V}O_{2max}$ for activities in which a true $\dot{V}O_{2max}$ is not attained. This usually occurs during work sample (task simulation) tests, which do not engage as much muscle mass as during running, cycling, etc.

## 1.2 Physical fitness in soldiers

The term *physical fitness* is not a single characteristic, but has several attributes or components.[13] Although there is a general agreement on what constitutes physical fitness, the various components may be categorized in different ways.[9, 13, 27] Different terms may also be used to describe similar components.

Vogel[27] categorized physical fitness according to energy pathway; anaerobic and aerobic (Table 1). Each pathway corresponds to some physiological or common terminologies. The anaerobic pathway can be divided into the alactic and the lactic system. Terminologies like peak anaerobic power and muscle strength correspond to the alactic system, while anaerobic power capacity and muscular endurance correspond to the lactic system. The aerobic pathway corresponds to terminologies like aerobic capacity and cardiopulmonary fitness.

**Table 1**. Categories of physical fitness in a military context, according to Vogel.[27]

| | **Anaerobic Pathway** | | **Aerobic Pathway** |
|---|---|---|---|
| Energy source/ pathway | Phosphogens/ phos. splitting (alactic) | Glycogen/ glycolysis (lactic) | Lipids/glycogen citric acid cycle |
| Primary determinant | Muscle mass | Muscle fiber make-up | Oxygen transport |
| Description | Very high intensity 1–5 seconds | High intensity 5–60 seconds | Moderate-low intensity 1 minute |
| Examples of activities | Lift Push Pull | Lifting Sprinting Climbing | Running Load bearing Walking |
| Physiological terminology | Maximal force/torque Peak anaerobic power | Anaerobic power capacity | Aerobic capacity |
| Common terminology | Muscle strength | Muscular endurance | Stamina Cardiopulmonary fitness |

Knapik et al.[13] categorized physical fitness into four components typically evaluated in soldiers: cardiorespiratory endurance, muscle strength, muscular endurance, and body composition. Later in this chapter I will build on Knapik et al.'s categorization, and present a brief review of how these four components can be evaluated in military personnel, followed by a short review of studies reporting physical fitness levels in various types of soldiers.

### 1.2.1 Testing physical fitness in soldiers

The various components of fitness may be evaluated through *physical ability tests* or by *work sample tests*.[1] These two overarching types of tests are explained later in this chapter. Irrespective of the type of fitness test: its validity, reliability, responsiveness and practical aspects should be considered prior to deciding which test to use on soldiers.[10, 11, 50]

**Validity** refers to how well a test measures what it is designed to measure.[51] There are three main categories of validity.[10, 52, 53] First, c*riterion-related validity* is established when a test is compared against 1) a recognized criterion measure, or 2) a direct measure of job performance. An example of the prior could include an investigation of the relationship between 3000 meter run test scores and directly measured $\dot{V}O_{2max}$, while the latter could include an investigation of the relationship between 3000 meter run test scores and performance during an aerobic demanding military field exercise. Physical ability tests are typically evaluated based on statistics from criterion-related validity studies. A second type of validity is *content validity*, which is based on how well the test seems to reflect important elements of the job.[10] Experts may evaluate content validity based on theoretical judgements, while non-experts interpret the quality of the test based on apparent characteristics and whether it looks relevant (also called *face validity)*. Work sample tests are often evaluated based on their content validity. The third type, *construct validity*, is used to validate measures that are unobservable, yet exist in theory (e.g. IQ tests).[52] This type of validity is more common in psychology than in physiology.[53]

**Reliability** refers to how consistent measurements are; in other words, the ability to reproduce measurements.[54, 55] We can divide reliability into *intra-rater* and *inter-rater* reliability.[55] The prior relates to the measurement error that occurs when the same rater (i.e. investigator) measures an item more than once. The latter type describes the measurement error observed when two or more different raters measure the same item.[55] Reliability can be expressed in relative or absolute ways. *Relative* reliability relates to how well individuals maintain their position in a sample with repeated measurements (usually expressed with a correlation coefficient). *Absolute* reliability is the degree to which repeated measurements vary for individuals (usually expressed in the actual units of measurements or with a dimensionless ratio).[56] Good reliability is a prerequisite for high validity; if a test is not reliable it will also not be valid.[52, 56]

**Responsiveness** is the ability of a test to detect a change over time (for example, in physical performance).[11, 57] It can also be named *sensitivity to change*. Responsiveness seems to be less frequently evaluated in exercise physiology studies, compared to validity and reliability.[11] This could be because a study of responsiveness usually requires an intervention design (costly),[58] or because good responsiveness can be assumed if a test is already confirmed to be both valid and reliable.

**Practical aspects** are also important when evaluating or selecting a fitness test. Respondent and administrative burdens should be considered.[11] A test that requires a lot of equipment, lab facilities, expert technicians and one-to-one testing may be too expensive and time consuming for regular use in the military. Injury-risk and whether the test encourages the soldiers to exercise in a beneficial way may also be taken into account.

#### 1.2.1.1 Physical ability tests

Physical ability tests intend to measure basic physical fitness components.[1] Such tests are also called *motor ability and fitness tests*,[53] *field-expedient fitness tests*,[9, 59] *generic predictive tests*[10] or *general fitness tests*.[60] The four military relevant fitness components identified by Knapik et al.[13] will be explained below, together with examples of corresponding physical ability tests used in the military.

**Aerobic capacity (cardiorespiratory endurance)**

During prolonged physical work, energy (adenosine triphosphate, ATP) is provided to the working muscles primarily based on aerobic pathways.[61] During a maximal work lasting 75 seconds, about 50 % of the energy is provided by aerobic processes (the rest is anaerobic).[62] The aerobic contribution increases for work exceeding this duration. Since oxygen consumption is directly related to aerobic energy transfer, a test of $\dot{V}O_{2max}$ will reveal an individual's maximum potential for aerobic energy transfer, and hence, the physiological potential for doing prolonged physical work. Although $\dot{V}O_{2max}$ is not the only factor related to performance during prolonged physical work (work economy, fractional utilization of $\dot{V}O_{2max}$, motivation, hydration, nutrition status, etc. are also important), it is clear that $\dot{V}O_{2max}$ plays a decisive role.[46, 63]

Maximal oxygen uptake can be measured or estimated from an abundant number of tests. Some classify these tests as *direct* and *indirect* tests,[64] which in many ways correspond to the terminologies *laboratory* and *field* tests.[47] Another distinction is made between *maximal* and *submaximal* tests.[65] Test modes include walking, running, cycling, stepping, swimming, and many more.

*Direct tests*

Maximal oxygen uptake can be measured directly by analyzing ventilation volume, and $O_2$ and $CO_2$ content in the air expired.[47, 66] Direct measurement of $\dot{V}O_{2max}$ during a maximal test until exhaustion is considered the "gold standard" method for assessing aerobic capacity.[67] It is usually conducted in a laboratory, with the subject cycling on a cycle-ergometer or walking/running on a treadmill. Portable devices make it possible to administer testing out of the laboratory as well. A direct test of $\dot{V}O_{2max}$ is rarely applied to mass-testing of soldiers, since it is time consuming, expensive, and requires access to laboratory facilities, equipment and trained staff. Hence, indirect tests are much more common in the military.

*Indirect tests*

Maximal field runs are probably the most common way of evaluating aerobic fitness in soldiers.[5] In the 1960s, Major K. Cooper from the US Air Force demonstrated a high correlation ($r$ = 0.90) between distance covered from 12 minutes of running and directly measured $\dot{V}O_{2max}$.[68] Although the 12 minute run ("Cooper's test") is still used in several nations, distance runs of 2–4 km are probably more common, due to ease of administration.[5, 24, 47, 69] Tests such as the 3 km run, the 1.5 mile run or the 2 mile run are confirmed valid predictors of $\dot{V}O_{2max}$ (relative to kilogram bodyweight) in military personnel.[70-72] However, unloaded running tests are somewhat criticized for not being optimal predictors of performance in a common military activity such as loaded marching, partly because heavy personnel are penalized in unloaded tests.[73-75]

The 20 m SRT (the multi-stage fitness test) is also a relatively common test within the military.[5, 24] This maximal test involves running back and forth between two lines 20 meters apart, with running speed increasing every minute. Validity and reliability of the 20 m SRT are examined in several studies of civilian subjects, primarily of younger age.[76-83] The test is less frequently validated in adults aged greater than 30 years.[78, 84] Previous studies on validity and reliability of this test applied on military personnel are scarce, but a validity report from the Swedish Armed Forces has recently been published.[85] Civilian studies generally demonstrate a relatively high correlation between the 20 m SRT and directly measured $\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$), and also demonstrate good reliability.

Maximal performance tests on treadmills[86-88] or cycle ergometers[89, 90] are also generally considered valid and reliable indirect tests of aerobic capacity. Although NATO previously recommended using a maximal watt cycle test protocol to measure aerobic fitness in their forces,[25] both treadmill and cycle test protocols are less frequently used for mass-testing of soldiers. This is probably because equipment and indoor facilities are needed for these protocols, in addition to their being more time consuming. Yet, a maximal treadmill protocol is used to screen 15,000–20,000 Norwegian prospective conscripts each year. The test is demonstrated to be equally valid to the 3000 meter run in estimating directly measured $\dot{V}O_{2max}$.[91] In Sweden, the maximal watt cycle test is used to screen prospective soldiers prior to enlistment.

Submaximal tests are also occasionally used to estimate aerobic fitness in soldiers. Such indirect tests are typically based on measuring heart rate (HR) at the end of a steady state work at a known/fixed load on a treadmill or a cycle ergometer, or after a stepping task. An extrapolated maximal work capacity (based on the assumed maximal HR) is calculated from the relationship between the submaximal HR and the corresponding load.[46, 92] In Norway, all prospective conscripts carried out the submaximal Åstrand-Ryhming cycle-ergometer test during the 1970s and 1980s.[93, 94] These days, submaximal testing seems to be less common in the military, probably because submaximal tests are found to be less valid in estimating $\dot{V}O_{2max}$ compared to maximal tests.[46] One example of a submaximal test still in use is the UKK walk test,[95] administered on Finnish reservists.[96] In subjects with low aerobic fitness levels, the UKK test may be viewed as a hybrid between a maximal and submaximal test, as the subjects are encouraged to walk 2 km as fast as possible.

**Muscle strength**

Muscle strength can be defined as the ability of a muscle group to exert a maximal force in a single voluntary contraction,[13] and determines the ability to lift, push and pull with maximal intensity for a short duration (Table 1). It is the alactic part of the anaerobic system that primarily provides energy for this type of work.[62] The alactic system refers to anaerobic splitting of ATP and creatine phosphate (CP) stored in the muscle cells, and this system provides immediate energy for maximal intensity work up to about 5–10 seconds. The cross-sectional area of the active muscles (i.e. the skeletal muscle mass) is closely associated with muscle strength.[97] One-repetition maximum bench press, back squat and clean are common methods of assessing muscle strength in athletes.[98] However, the need for equipment, the time (efficiency), and the injury risk make traditional one-repetition maximum dynamic tests less common for use in the military – although variations of such tests are or were previously used.[99] Isometric (static) one-repetition maximum tests may be more time efficient and have lower injury risk, and are sometimes used in military settings. The simple handgrip test is one such example,[5] while isometric leg and chest press are used today to screen Norwegian prospective conscripts. However, isometric tests are generally considered less valid than dynamic tests.[100]

The term *power* means the ability to develop the highest possible force as rapidly as possible.[13] Muscle strength and power are both based on the alactic energy system, and are often discussed concurrently.[98] Furthermore, muscle strength and power may correlate well with each other, as long as both tests are based on absolute or relative-to-body weight measures.[101, 102] NATO has previously recommended medicine ball throw, vertical jump and standing long jump as simple and valid tests of muscular power and strength suitable for mass-testing of soldiers.[25]

**Muscular endurance**

Knapik et al.[13] defined muscular endurance as the ability of a muscle group to perform short-term, high-intensity physical activity lasting for a short period of time (generally < 1.5 minutes). As presented in Table 1, the physiological terminology that corresponds to muscular endurance is anaerobic (power) capacity. Anaerobic capacity includes the capacity of the alactic and lactic system combined, and can be defined as the amount of ATP regenerated from anaerobic metabolism in a specific type of exercise of short duration.[103] In contrast to aerobic capacity, no direct method of anaerobic capacity measurement exists.[62] Hence, indirect methods like measuring blood lactate concentration, "the oxygen debt", the "maximal accumulated oxygen deficit" and various performance tests have been developed. However, their validity may be questioned, as there is no direct gold standard measurement to compare against.[62, 103] Performance tests are the only realistic method to use in the military. The 30 seconds Wingate cycle ergometer test is one such option, while other options include various jump tests and running tests on track or treadmill.[104] The 200–400 meter run may be a practical anaerobic capacity test for military use, as it is less dependent on equipment. It has been claimed that such a running test gives a relatively valid measure of anaerobic capacity relative to body weight.[105, 106] An anaerobic capacity test typically lasts ≤ 60 seconds, in order to minimize the aerobic contribution during the work.

Pure anaerobic capacity tests, like the ones mentioned above, are not frequently used in the military. Instead, push-ups, sit-ups, pull- or chin ups are common tests of anaerobic capacity or muscular endurance. However, the duration of such tests may vary greatly between subjects and between types of test. A sit-ups test may last for 2 minutes, while some may not be able to do one pull-up. Hence, these "muscular endurance" tests may in fact measure either maximal strength, anaerobic capacity, or a combination of aerobic and anaerobic capacity.[25, 52] Moreover, the validity of these tests to predict relevant military physical performance has been questioned.[25, 73, 107]

**Body composition**

One could question whether body composition should be categorized as a separate fitness component. Vogel did not include body composition in his figure on categories of fitness (Table 1), while Knapik et al.[13] stated that body composition is often referred to as a component of physical fitness because of its interaction with other fitness factors. Body composition may be expressed utilizing different models.[108] A simple and much used model is the whole-body two component model that distinguishes between body fat (BF) and fat free mass (FFM). Another model is the anatomic four component model, of which adipose tissue and skeletal muscle mass are the two most relevant components in terms of military physical performance.

There is no universally accepted gold standard method for body composition measurement.[109] However, underwater weighing (also named hydrostatic weighing or hydrodensitometry), air displacement plethysmography, hydrometry, whole-body counting of potassium ($^{40}K$), DXA, magnetic resonance imaging and computed tomography are among the methods considered valid and often referred to as reference methods.[108-110] Such laboratory methods are usually not applicable for mass-screenings of soldiers, and easier field methods are typically used in military populations.

Body mass index is probably the easiest and most basic body composition method, but it may be inaccurate on the individual level since it does not differentiate between muscle mass and fat mass.[111] Hence, an athletic person with high muscle mass might be classified as overweight. While BMI is not considered a valid estimate of body composition in individuals, it has merit as a health and body composition indicator at group level.[112]

Another practical and quick measurement is the waist (or abdominal) circumference (WC). Although WC is often considered more valid than BMI in predicting cardiometabolic risk,[113] some claim it is not superior to BMI when estimating adiposity in adults[114-116] or when classifying obesity in military personnel.[117] However, others state that the WC method is even superior to the sophisticated reference methods in regards to the outcome of military interest.[118] The US military uses WC (in addition to other circumference sites) as a second option for personnel exceeding the BMI limits.

The skinfold (SKF) method is based on the principle that there is a relationship between subcutaneous BF and total BF.[119] Thus, SKF thickness is measured at standardized anthropometrical sites. Fat free mass or BF can be calculated from prediction equations, either directly based on SKF or via body density (BD) estimations. Skinfolds may correlate well ($r$ = 0.7–0.9) with percent BF and FFM, if the technician is properly trained and experienced.[65, 110] The method does not seem to be very common for mass-testing in the military, possibly because experienced technicians are needed to get accurate measurements and because other field methods are quicker.

The BIA method is based on the principle that electric current flows at different rates through the body depending on its composition. The resistance and reactance measurements are used to predict total body water, FFM or BF from various equations.[120] A BIA device is based on single frequency (SF) or multi-frequency (MF) measurements.[121] It is claimed that the accuracy of BIA is similar to SKF, if the hydration levels of the subjects tested are normal.[65] Both methods rely on using prediction equations that are valid for the population tested. Bioelectrical impedance analyses are quick, and the devices are easy to operate for the investigator. Single frequency BIA devices are typically small, portable, cheap, and easy to use in the field – while the MF devices are more expensive and less portable.

#### 1.2.1.2 Work sample tests

While a physical ability test is designed to measure basic physiological/fitness components, a work sample test evaluates how well a person carries out a critical work task or a series of important tasks.[1] Work sample tests are also known as *task simulation tests*,[10] or *combat/functional fitness tests*.[9] The advantage of a work sample test is that it simulates actual working conditions, and its relevance is usually apparent for those being tested (high face validity). Hence, work sample tests are often evaluated based on content validity, as well as their criterion-related validity. Limitations of work sample tests include that they may have limited application since they reflect specific scenarios, they often require equipment or complex set-ups, injury risk may be elevated, the sometimes used pass/fail approach gives a rather crude rating of those tested, and the skill-factor may have high influence on the result.[1, 59, 122] Some military-relevant work sample tests are presented in Table 2.

**Table 2**. Examples of work sample tests used on military personnel

| Name | Description | Reference |
|---|---|---|
| Backpack run test | 2 mile run with backpack (total external weight approx. 30 kg) in the fastest possible time. | Vanderburgh & Flanagan[75]<br>Spiering et al.[123] |
| Obstacle course test | Negotiate several obstacles (hurdles, crawl, wall traverse, zig-zag sprint, jumping etc.) in the shortest possible time. | Pandorf et al.[124]<br>Jetté et al.[125]<br>Bishop et al.[126] |
| Repetitive box lift | Lift as many 20.5 kg boxes as possible from the ground onto 1.3–1.6 meter high platforms in 10 minutes. | Pandorf et al.[124]<br>Spiering et al.[123] |
| Single box lift | Lift boxes from the ground to approx. 1.5 meter height. Weight of the heaviest box lifted is registered. | Richmond et al.[127]<br>Spiering et al.[123]<br>Williams & Evans[128] |
| Fire and maneuver/ combat rushes | A combination of standing up, running, laying down, crawling. This is repeated several times, and total time (or a pass/fail) is registered. | Richmond et al.[127]<br>Spiering et al.[123]<br>Silk & Billing[129] |
| Digging | Shoveling a defined mass of shingle within the shortest possible time. | Richmond et al.[127]<br>Stevenson et al.[130] |
| Jerry can carriage | Lift and carry two Jerry cans (15 or 22 kg) a distance of 25 meters in 20 seconds. Repeated until volitional fatigue. Total meters registered. | Beck et al.[131] |
| Stretcher carriage | Simulation of stretcher carriage on a 55 meter course. Maximum weight to carry is 90 kg. Evaluated as pass or fail. | Von Restorff[132] |
| Evacuation test | Dragging of mannequin a defined distance, in the shortest possible time. | Angeltveit et al.[133]<br>Spiering et al.[123] |
| Combination of tests | A combination of several work sample tests. Different protocols in Canadian Forces, German Forces and US Marine Corps. | Gagnon et al.[134]<br>Rohde et al.[135]<br>US Marine Corps[136] |

### 1.2.2 Levels of physical fitness in soldiers

Information about soldiers' physical fitness levels may be extracted from several published cross-sectional studies, intervention studies and method comparison studies. Study design, sampling strategies, participation rate and sample size influence how well suited the studies are in describing fitness levels of various types of military personnel. Moreover, differences in test protocols, measurements units, etc. may hamper direct comparisons between studies. For instance, there seem to be no standard one-repetition maximum muscle strength tests used across different nations, and muscle endurance tests such as push-ups or sit-ups may be administered in different ways.[72, 96]

Since $\dot{V}O_{2max}$ and BF are typically expressed in the same units across different studies, and because these two physiological components are key parameters in this thesis, Table 3 only presents identified studies reporting values of $\dot{V}O_{2max}$ (measured directly or estimated) and body composition (percent BF). Additionally, Table 3 includes data restricted to male soldiers and baseline results from longitudinal studies.

For further reading, more studies on aerobic fitness (from field running tests), muscle endurance and muscle strength are published on male and female soldiers from, among others, USA,[13, 137-140] Canada,[16] Israel,[141-143] Finland,[144-147] UK,[23, 148] Germany,[149] Switzerland,[150, 151] Sweden,[152] and Norway.[153, 154] Physical fitness data for reserve soldiers are rarely reported in the literature, with studies on US, UK and Finnish reserves among the few identified (Table 3).

**Table 3**. A selection of published studies on maximal oxygen uptake and body fat in male soldiers since year 2000. Results presented as mean with standard deviations (SD)

| Fitness component | Subjects and test employed | Results | Reference |
|---|---|---|---|
| $\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$) | 120 German SOF police—directly measured, running | 57.4 (4.3) | Sperlich et al.[155] |
| | 26 Norwegian Air Force cadets—directly measured, running | 57.0 (N/A) | Aandstad et al.[156] |
| | 51 Canadian SOF candidates—directly measured, running | 55.0 (3.7) | Carlson et al.[157] |
| | 84 Norwegian infantry soldiers—directly measured, running | 54.8 (4.8) | Dyrstad et al.[154] |
| | 104 Australian SOF candidates—estimated, 20 m SRT | 54.5 (3.1) | Hunt et al.[158] |
| | 34 UK marines—estimated, 20 m SRT | 53.1 (4.0) | Fallowfield et al.[159] |
| | 34 UK Navy personnel—directly measured, running | 52.6 (5.2) | Bilzon et al.[160] |
| | 41 Israeli recruits—directly measured, running | 50.9 (7.2) | Evans et al.[143] |
| | 103 US Army deployed soldiers—directly measured, running | 50.8 (6.1) | Sharp et al.[161] |
| | 171 US Army recruits—directly measured, running | 50.6 (6.2) | Sharp et al.[137] |
| | 39 Polish Army recruits—directly measured, cycling | 49.8 (6.3) | Faff et al.[162] |
| | 53 US National Guard soldiers—directly measured, running | 49.7 (8.7) | Warr et al.[139] |
| | 35 US Army deployed soldiers—estimated, 2 mile run | 48.6 (5.1) | Lester et al.[163] |
| | 21 UK Reserve Army soldiers—estimated, 20 m SRT | 47.2 (3.4) | Williams et al.[128] |
| | 28 Israeli recruits—directly measured, running | 45.9 (7.9) | Yanovich et al.[142] |
| | 57 Finnish conscripts—directly measured, cycling | 45.0 (8) | Santtila et al.[164] |
| | 891 Finnish reservists—estimated, cycling | 42.7 (7.2) | Fogelholm et al.[146] |
| | 686 Finnish reservists—estimated, cycling | 41.6 (8.1) | Vaara et al.[145] |
| | 20 UK Reserve Army soldiers—estimated, 20 m SRT | 38.8 (7.5) | Williams[165] |
| Body fat (%) | 57 Finnish conscripts—SKF | 10.4 (4.4) | Santtila et al.[164] |
| | 20 UK Reserve Army soldiers—SF-BIA | 14.5 (4.5) | Williams[165] |
| | 39 Polish Army recruits—SKF | 15.0 (3.3) | Faff et al.[162] |
| | 34 UK Navy personnel—SKF | 16.7 (3.5) | Bilzon et al.[160] |
| | 42 Croatian Naval servicemen—SKF | 17.1 (2.9) | Sporis et al.[166] |
| | 85 UK marines—SKF and circumferences | 17.2 (4.9) | Fallowfield et al.[159] |
| | 28 Israeli recruits—SKF | 17.4 (4.9) | Yanovich et al.[142] |
| | 110 US Army deployed soldiers—DXA | 17.7 (6.4) | Sharp et al.[161] |
| | 30 Norwegian Air Force cadets—SF-BIA | 17.8 (N/A) | Aandstad et al.[156] |
| | 839 Finnish reservists—MF-BIA | 17.9 (7.2) | Vaara et al.[145] |
| | 182 US Army recruits—SKF | 18.7 (4.8) | Sharp et al.[137] |
| | 73 US Army deployed soldiers—DXA | 18.9 (5.5) | Lester et al.[163] |
| | 626 US Navy and Marine Corps personnel—circumferences | 19.1 (N/A) | Graham et al.[167] |
| | 21 UK Reserve Army soldiers—SF-BIA | 20.4 (3.5) | Williams et al.[128] |
| | 53 US National Guard soldiers—air displacement pleth. | 22.2 (9.2) | Warr et al.[139] |
| | 140 Finnish conscripts—DXA | 22.6 (9.7) | Mattila et al.[168] |
| | 297 US Navy submariners (age 20–39) —DXA | 27.3 (6.4) | Gasier et al.[169] |

20 m SRT, 20 meter shuttle run test; DXA, dual-energy X-ray absorptiometry; MF-BIA, multi-frequency bioelectrical impedance analysis; N/A, not available; SF-BIA, single frequency bioelectrical impedance analysis; SKF, skinfold; SOF, Special Operation Force; $\dot{V}O_{2max}$, maximal oxygen uptake.
Baseline values are presented for longitudinal studies.

## 1.3 Physical activity in soldiers

This chapter includes a brief review of different methods commonly used to measure and report physical activity levels, followed by a description of physical activity levels reported in soldiers (including reserves).

### 1.3.1 Assessing physical activity

Physical activity can be assessed in several ways. Vanhees et al.[170] claim the different methods can be categorized into three groups; criterion methods, objective methods and subjective methods. Criterion methods include doubly labelled water (DLW), indirect calorimetry and direct observation.[171] Objective methods include various forms of physical activity monitors (e.g. accelerometers and pedometers) and HR monitoring. Finally, questionnaires and diaries are considered subjective methods. Others have categorized the different ways of assessing physical activity for direct or objective methods versus indirect or self-reported methods.[172-175]

*Criterion methods*

The DLW method has been claimed to be the gold standard method of physical activity measurement.[173, 176] It is used to measure total energy expenditure (TEE) over a period of about 4 – 21 days.[177] The subjects drink water labeled with isotopes of $^{2}H$ and $^{18}O$, and $CO_2$ production is calculated (from urine samples) from the difference in elimination rate between the two isotopes. The $CO_2$ production is used to calculate the TEE.[170, 178] While DLW produces valid measures of TEE, it is costly and can only provide average values for several days combined (no information about time in different intensity zones).[177] The DLW method is primarily used to validate more simple and indirect methods, and is not commonly used in large scale studies.[170]

Indirect calorimetry is another reference method from which energy expenditure can be calculated. Indirect calorimetry includes several methods, but the most practical involves direct measurements of $\dot{V}O_2$ from a portable oxygen analyzer.[170, 179] With this technique, information about intensity for short periods of time (seconds or minutes) may be collected, which is an advantage over the DLW method. As with DLW, indirect calorimetry is still too expensive and impractical to be used in large scale studies, but the method is useful for validating other physical activity measurement methods.

During direct observation, information about type of physical activity, duration, frequency, intensity etc. are collected, and metabolic rates may be calculated from a compendium.[180] Since an observer must follow each subject the entire time for a designated period, this method is very time consuming and expensive, and not applicable for large scale studies.[170] A major strength is that it gives access to contextual information.[176] This method appears to be less common today, as alternative criterion methods (DLW and indirect calorimetry) seem more feasible.

*Objective methods*

Objective methods (wearable monitors) are now commonly used for evaluating physical activity in clinical settings and in research. Since the criterion methods are usually not realistic to use, the second best choice is often considered a wearable physical activity monitor. Such monitors provide more accurate assessments of physical and mechanical parameters that correspond to physical activity, compared to self-reported methods (questionnaires etc.), since they are not subject to reporting bias and recall problems.[172, 173] They may be used to gather data over several days, and calculate TEE, time in different intensity zones, steps, etc. Butte et al.[14] claim that six types of wearable monitors exist today; 1) pedometers, 2) accelerometers, 3) HR monitors, 4) multiple sensor systems, 5) combined accelerometer and HR monitors, and 6) load transducers (foot-contact monitors). There is no gold standard among these different monitors, but the four first types are most frequently used[172] and will be briefly described below.

Pedometers are easy to use and low cost instruments that measure steps, which may be converted into distance or TEE.[181] Some models measure the number of steps accurately, while others produce overestimated or underestimated results.[182] Pedometers are less valid in estimating TEE, since horizontal and upper-body movement are not recorded.[14] Thus, activities like swimming, cycling, strength training, and carrying load are not well reflected from pedometer measurements.[170]

Accelerometers are small monitors typically worn on the hip (alternatively on the wrist or ankle), which record accelerations in gravitational units.[172] Modern tri-axial accelerometers measure magnitude and direction of the acceleration in three planes, while earlier models were uni- or bi-axial monitors.[183] The data are processed and usually expressed in “counts”. Based on certain thresholds for counts per minute, minutes of physical activity in different intensity zones are typically presented. With an accelerometer it is possible to measure physical activity in a detailed and relatively precise way, with minimal invasiveness.[172] Quite a few studies during recent years have used accelerometers to measure habitual physical activity, thus, reference data are available for comparison purposes. Limitations include the inability to detect more static activities like weight lifting, activities without vertical movement (e.g. cycling) and underestimations during movement with load carriage.[173] This may partially explain why the correlation between accelerometer determined counts and directly measured $\dot{V}O_2$ (or metabolic equivalents, METs) varies among different studies, leading to some doubt about the validity of accelerometers.[184, 185] Moreover, lack of standardization when converting raw data into counts, and the use of proprietary algorithms, are other limitations.[14, 172]

Heart rate monitoring is another objective method to assess physical activity. It is based on the linear relationship between HR and energy expenditure.[14] This relationship is strong for moderate and more vigorous physical activity, but weaker for light intensity since HR during rest/light intensity may be confounded by several factors (e.g. caffeine, stress and smoking).[170] Temperature, humidity and dehydration may also influence the HR-$\dot{V}O_2$ relationship.[46] Since different subjects vary in aerobic fitness levels, individual relationship between HR and energy expenditure (from $\dot{V}O_2$ measurements) must first be established from measurements during activities of different intensity levels.[177] However, the established HR-$\dot{V}O_2$ curve is specific for the activity used during this calibration process, and may not be valid for all types of free-living activities. Ideally, several calibrations should be carried out for different types of activities. Thus, obtaining valid estimations of physical activity levels from HR monitoring could be rather time consuming. Compared to accelerometers, HR monitoring is a more valid method during non-ambulatory and upper body activities like load carriage, weight lifting and cycling. Yet, Westerterp[176] ranked accelerometers higher than HR monitors in relation to their overall ability to measure physical activity objectively, and claims that HR monitoring does not give an accurate picture of physical activity on the individual level.

Multiple sensor systems combine multiple physiological and mechanical sensors to calculate physical activity and energy expenditure.[172] Such systems or devices may include parameters like accelerometry, respiration, HR, skin temperature and global positioning system (GPS). The advantage of such systems is the assumed increased precision, as the different parameters may capture different types of activity and movements. Data from the different parameters are processed further with algorithms that generate data like TEE, steps and minutes in different physical activity zones. Device-specific proprietary algorithms are often used, which may inhibit comparisons between different systems and insight into how output data are processed and estimated.[186] Other disadvantages are that multiple sensor systems are typically complex and costly.[14] One example of a multiple sensor system is the SenseWear Armband which we used in the present study (see methods chapter and Paper IV).

### 1.3.2 Levels of physical activity in soldiers

Self-reported physical activity levels of military personnel have been described in several large scale studies in various military populations from several countries.[146, 187-192, 192-194] International studies reporting objectively measured physical activity levels in representative samples of soldiers are much scarcer. After reviewing the literature, these studies are presented in Table 4. Note that only one study pertains to reserve soldiers.[195] Only studies presenting TEE, steps, accelerometer counts, or minutes in different intensity zones are included. More often, objectively measured physical activity is reported in small scale studies with other research aims than reporting population values. Tharion et al.[42] reviewed many such studies of TEE during military training in the field or during life in the garrison. It should be mentioned that TEE is not an accurate measure of physical activity level in individuals *per se*, since it is dependent on body size, body composition, age and gender.[196, 197]

**Table 4**. Objectively measured physical activity in different types of soldiers. Values are mean (SD) per day, if not otherwise stated.

| Type of soldiers and condition | N (♂♀) | PA variable | Value | Reference |
|---|---|---|---|---|
| US Army National Guard soldiers who had failed the 2 mile run test, measured at baseline during intervention project. | 94 ♂♀ | Steps (no.) (pedometer) | 6415 (2858) to 7300 (4064) | Talbot et al.[195] |
| US Army soldiers measured during 9 weeks of basic combat training. | 57 ♂♀ | Steps (no.) (pedometer) | 16311 (5826) | Knapik et al.[198] |
| US Army recruits measured during 6 weeks of basic combat training at two sites. | 264 (N/A) | Time (hh:mm) in ≥ 3 METs (accelerometer) | 02:04 to 02:16 | Simpson et al.[199] |
| Swiss Army recruits from 5 specialties measured during 4 weeks of basic training. | 214 ♂ | TEE (Mj) (MSS) | 15.4 (1.8) to 20.5 (1.0) | Wyss et al.[200] |
| German Navy and Air Force soldiers and officers measured during 7 days of regular military duty. | 169 ♂♀ | Steps (no.) (accelerometer) | 539 (228) to 838 (309)* | Schulze et al.[201] |
| US Army military personnel (or family members) with BMI ≥ 25, measured at baseline during intervention project. | 89 ♂♀ | Steps (no.) (pedometer) | 7404 (3275) | Staudter et al.[202] |
| Finnish Army conscripts during 8 weeks of basic training (daytime only). | 35 ♂ | Time (hh:mm) in ≥ 4 METs (accelerometer) | O2:07 (00:24) | Tanskanen et al.[203] |

BMI, body mass index; hh:mm, hours and minutes; METs, metabolic equivalents; Mj, megajoule; MSS, multiple sensor system; no., number; N/A, not available; PA, physical activity; TEE, total energy expenditure; ♂, men; ♀, women.
* Values reflect steps/hour during military duty hour.

## 1.4 The Norwegian Home Guard – history, structure and function

The Norwegian HG was officially established in 1946.[204] The force was founded based on local resistance groups during World War II, in particular the Milorg group.[205] The HG consisted of about 100,000 soldiers at the time it was established, and the soldiers were organized in 18 districts.

In 2004, the number of HG districts was reduced from 18 to 13, while the number of soldiers was reduced from 80,000 to 50,000. The force was split into three types: 1) the Rapid Reaction (RAP) HG force with 5000 soldiers, 2) the Regular (REG) HG force with 25,000 soldiers, and 3) the Reserve force with 20,000 soldiers.[205, 206] The troops and soldiers could now also operate in other districts than their home district, and new and more modern equipment was acquired. The changes were part of what was named the “quality-reform of the HG”.

Today, in 2017, the HG is organized in 11 districts, with 45,000 soldiers in total (including 3000 RAP-HG soldiers). All 11 districts have land based soldiers organized in both RAP-HG force and the REG-HG force. In addition to the land based forces, separate Naval and Air Force units exist within the HG.[207]

Soldiers in the HG typically have a one year compulsory conscription service as their military background before being selected for the HG. Others have higher military education from one of the officer schools, or served as professional soldiers in one of the other military branches. Service in the HG is obligatory, and lasts until the soldier is 44 years old (55 years for officers). HG soldiers who want to serve in the RAP-HG force have to apply separately. Applicants must also pass physical fitness tests to be qualified for this voluntary service. Soldiers in the RAP-HG force are expected to meet for military training 15–25 days per year, while REG-HG soldiers train for about 5 days per year. However, the number of days of military training varies, and budget cuts have typically reduced the training volume.

The HG has the main responsibility of safeguarding the Norwegian territorial integrity. The HG also assists the professional military forces, the police or other civilian authorities during military crisis, natural disasters and rescue operations.[208] Typical job tasks for the REG-HG are securing objects, road checks and border controls. The RAP-HG is also trained for the same tasks, including more mobile warfare. The HG only operates within Norway, but individual HG soldiers and officers might volunteer for international service. Some examples of work carried out by the HG in recent years are support during a large forest fire in 2008 and support during the extreme weather (“Dagmar”) in 2011.[209] The HG also frequently assists during rescue operations of missing people, often in mountain areas with challenging topography.[210]

## 1.5 Background for project

As previously discussed, there is general agreement that military work can be physically challenging, and that physical fitness is a prerequisite for safe and efficient execution of many military tasks. This also applies to military reserve forces like the Norwegian HG. Accordingly, the Inspector General of the HG included physical fitness as a focus area within the 2004 "quality-reform of the HG". When our Institute was contacted by the Inspector General, our recommendation was to first screen the fitness levels of HG soldiers. No previous studies had looked at physical fitness levels, physical activity levels, or physical job demands in Norwegian HG soldiers and studies in these fields were therefore needed. Moreover, few international studies had previously reported physical fitness and physical activity levels in representative samples of reserve soldiers, and increased research into health, physical fitness and readiness of reservists was recommended in the international literature.[139, 211]

With support from the Inspector General of the HG, a two-phase pilot project was established in 2004. About 60 soldiers from two troops in HG district 04 were included in this study. In phase one, the soldiers underwent direct $\dot{V}O_{2max}$, strength and body composition measurements. The main aims were to map the fitness levels of HG soldiers, and conclude which tests the HG could utilize to select soldiers for the new RAP-HG force. In phase two, the effect of different physical activity motivation strategies was studied, with fitness and activity levels as outcome measures. Results from the pilot project were published as a report and at a conference.[212-214]

After the pilot project was completed, we recommended that the Inspector General of the HG proceed with a larger and more representative study on physical fitness and physical activity in HG soldiers. The Inspector general supported this idea, and the *Moving Home Guard Soldiers Study* [*Hele HV i bevegelse*] was established.

To be able to give trustworthy answers related to physical fitness and physical activity levels, it is necessary to evaluate the quality of the measurement tools. Although our key test-variables have previously been validated by others in primarily civilian studies, it is preferable to examine validity and reliability of a test on subjects with characteristics similar to those later screened. We decided therefore to investigate validity and reliability of the 20 m SRT and body composition field methods on Norwegian HG soldiers or other Norwegian military personnel.

## 1.6 Aims

The main objective of this thesis is to present representative data on physical fitness and physical activity in Norwegian HG soldiers. Another aim is to investigate validity and reliability of the key measurement tools used to evaluate physical fitness. The two studies on validity and reliability of the measurement tools will be presented first, as they are essential for the subsequent interpretation of the descriptive physical fitness data.

Specific aims of the four papers included in this thesis are as follows:

1. Investigate reliability and validity of the 20 m SRT in military personnel – using existing $\dot{V}O_{2max}$ prediction equations and our new equation (Paper I)
2. Investigate reliability and validity of body composition field methods in predicting percent BF in male and female soldiers – using several existing prediction equations (Paper II)
3. Present reference data for anthropometrics, body composition and aerobic capacity in Norwegian HG soldiers (Paper III)
4. Present reference data for objectively measured physical activity levels in HG soldiers, and investigate whether physical activity levels differed between civilian life and HG military training (Paper IV)

Moreover, the results from Paper III and IV will be used to discuss whether Norwegian HG soldiers are "fit to fight" – in other words, whether physical fitness levels are sufficient for the tasks required of the HG.

# 2 METHODS

This thesis is based on data collected from three separate studies (Figure 2). Paper I consists of data collected in the *Moving Home Guard Soldiers Study*, together with data collected in a pilot for the *Cadet Development Study*. Home Guard soldiers and Air Force cadets were included as subjects. Paper II is based on data from a study entitled the *Body Composition Method Comparison Study*. Participating subjects were cadets, soldiers and officers from the Air Force. Papers III and IV were written based on the Moving Home Guard Soldiers Study, which recruited both REG-HG and RAP-HG soldiers.

We applied to the Regional Committee for Medical and Health Research Ethics (REK) to review the three abovementioned studies prior to study start-up. The committee approved the Body Composition Method Comparison Study and the Moving Home Guard Soldiers Study, while the Pilot – Cadet Development Study was considered exempted from notification. The Norwegian Social Science Data Services (NSD) also approved the Body Composition Method Comparison Study and the Moving Home Guard Soldiers Study, while we did not apply for the Pilot – Cadet Development Study. Subjects volunteered to participate by giving their written consent after having received written and oral information. The studies were carried out according to the guidelines in the Declaration of Helsinki.[215] Feedback letters from REK and NSD, together with the information letters used in the three studies, are given in Appendices 1–3.

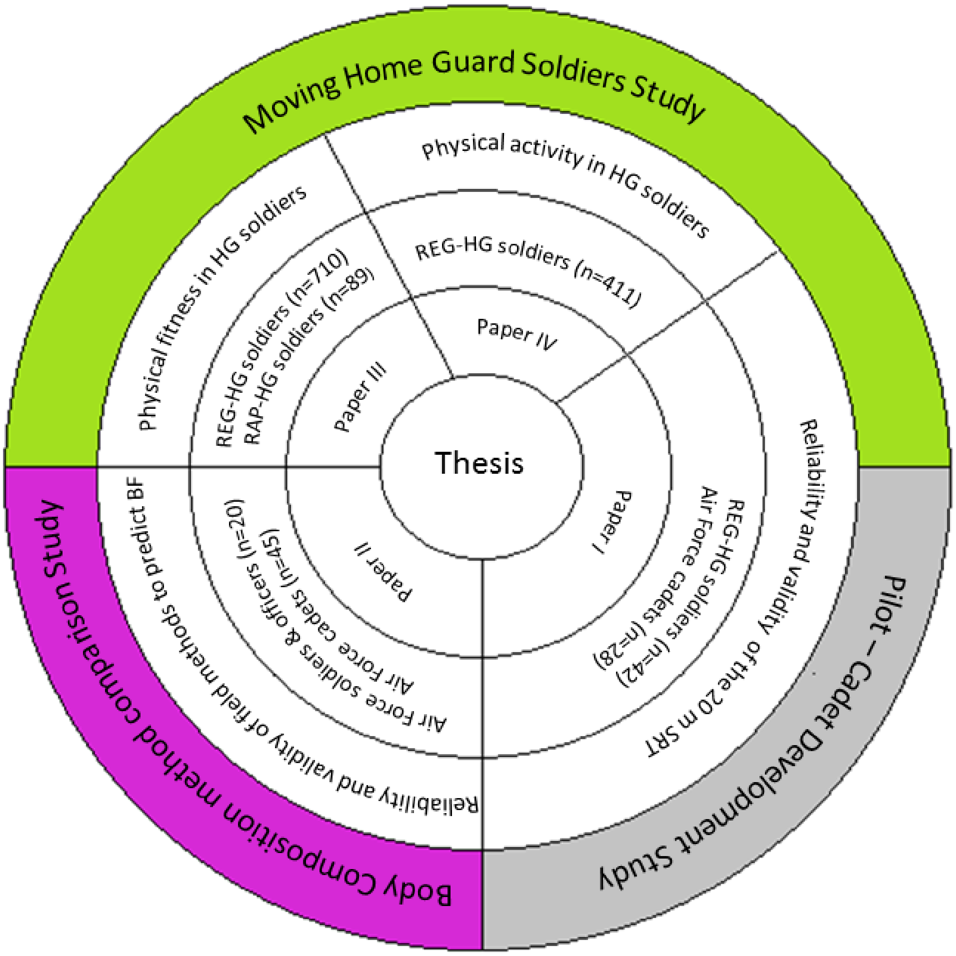


**Figure 2**. Overview of the present thesis. The outer (first) circle gives the titles of the three research studies this thesis is based on. The second circle shows the main theme of the four papers. The third circle shows the subjects included in the four papers of this thesis.

20 m SRT, 20 meter shuttle run test; BF, body fat; HG, Home Guard; RAP, Rapid Reaction; REG, Regular.

## 2.1 Study design

Papers I and II are based on studies characterized as method comparison studies.[216] They include both validity and test–retest reliability analyses. Papers III and IV are based on studies which employed a descriptive cross-sectional design.[216] All studies may also be characterized as observational studies.[217]

## 2.2 Subjects and sampling

### 2.2.1 Pilot – Cadet Development Study

All first year cadets (30 men and 1 woman) at the Royal Norwegian Air Force Academy (entry autumn 2006) volunteered to participate in the study. To preserve anonymity, and because estimation of $\dot{V}O_{2max}$ from running performance might be different between genders,[218] the woman's data were excluded from the analysis. Additionally, two subjects were injured on the days of the 20 m SRT testing; hence 28 male cadets were included in the study. Mean (SD) age among the participating cadets were 23 (4) years (range 19–38 years). All data were collected within one week in August 2006.

### 2.2.2 Body Composition Method Comparison Study

All first year military cadets (39 men, 6 women) at the Royal Norwegian Air Force Academy (entry autumn 2009) volunteered to participate in the study. In addition, all female military recruits (n = 13) from one troop at Ørland Main Air Station volunteered to participate in the study. Moreover, all 18–35 year old female military officers at Ørland were invited to participate in the study (unknown n), and 7 subjects volunteered. Data from the females from the two locations were collapsed. Mean (SD) age for men and women were 22 (2) and 21 (4) years, respectively. Age ranged from 19 to 27 years among the men, and 18 to 30 years among the women. All subjects were of Caucasian origin, and data were collected during two weeks in August 2009.

### 2.2.3 Moving Home Guard Soldiers Study

All 13 HG districts were first located in five groups based on geographical region; North, South, East, West and Mid Norway (Table 5). One HG district from each group was then randomly selected to participate in the study. However, if two selected HG districts had planned their annual HG training at the same week, another district was randomly chosen. The final five selected HG districts all accepted the invitation to participate in the study. Each HG district was visited twice between year 2006 and 2009 during scheduled HG military training, except for district HG-12 which was visited three times. Between two and six troops were randomly selected to participate at each visit. All soldiers in the selected troops were invited to participate. In other words, a cluster-randomization method was used. A total of 38 troops were included in the study, and four of these troops consisted of RAP-HG personnel. The participating RAP-HG soldiers and officers were recruited from HG districts located in West and Mid Norway, while the REG-HG personnel were recruited from all five districts.

All available soldiers and officers (928 men, 1 woman) in the selected 38 troops received information about the study and were invited to participate (Figure 3). One hundred ten subjects (12 %) declined to participate, while 19 subjects were later excluded due to assumed inadequate randomization (not under control by the project leader). As there was only one female subject, her data were excluded from the analysis. Thus, 799 men (89 belonged to the RAP-HG force) volunteered and met the inclusion criteria (Figure 3). Almost all of these soldiers carried out the anthropometrical and body composition measurements, while only 691 ran the 20 m SRT. Although both REG-HG and RAP-HG soldiers underwent physical activity monitoring, we chose to only present data for the REG-HG soldiers in Paper IV, since relatively few RAP-HG soldiers produced valid data during HG training (n = 12). Since the number of volunteer subjects in some troops outnumbered the available monitors, 128 randomly selected soldiers were not offered monitors. Moreover, some monitors were not returned, some data were lost because of technical errors, some soldiers declined to wear the monitor and some soldiers did not wear the monitor for a sufficient amount of time (Figure 3). Thus, only 411 soldiers produced acceptable monitor data during civilian life, of which 299 subjects also produced acceptable data during HG military training.

Within the REG-HG sample, 69 were reserve HG officers (civilians who act as officers during scheduled HG training), while 641 were private HG soldiers (civilians who act as soldiers during scheduled HG training). Within the RAP-HG sample, seven of the subjects were full-time officers (employed 100 % by the Norwegian HG), 26 were reserve HG officers and 56 were private HG soldiers. In most analyses, subjects were categorized as either REG-HG soldiers (which includes REG-HG private soldiers and officers) or RAP-HG soldiers (includes RAP-HG private soldiers and officers). However, in some cases the subjects were categorized as private soldiers or officers (which includes full-time and reserve officers).

Age ranged from 18 to 44 years among the 799 soldiers. Mean (SD) ages were 33 (5) and 28 (7) years for the REG-HG and RAP-HG soldiers, respectively ($P < 0.001$). Dividing the subjects according to rank, the mean (SD) ages of the private soldiers and officers were 32 (5) and 32 (6) years, respectively ($P = 0.834$).

Forty-two of the 799 participating HG soldiers also volunteered to take part in the 20 m SRT method comparison study (Paper I). These 42 soldiers were recruited from two REG-HG troops (district HG-02) consisting of 59 soldiers (participation rate 71 %). Some soldiers withdrew or were not able to meet for all tests. Hence, 38 and 41 soldiers are included in the validity and reliability analysis, respectively.

**Table 5**. Sampling during the Moving Home Guard Soldiers study

| Region | All existing HG districts | HG district selected | Data collection period, week (yr.) | No. of troops participating | Invited to participate (n) | Volunteered and included in study (n) |
|---|---|---|---|---|---|---|
| East | HG-01 | HG-02 | 45 & 46 (2006) | 4 X REG | 91 | 86 |
| | HG-02 | | 10, 11 & 12 (2007) | 6 x REG | 157 | 137 |
| | HG-03 | | | | | |
| | HG-05 | | | | | |
| South | HG-07 | HG-07 | 38 & 39 (2006) | 2 x REG | 84 | 50 |
| | HG-08 | | 25 & 26 (2007) | 3 x REG | 72 | 67 |
| West | HG-09 | HG-09 | 19 & 20 (2007) | 4 X REG | 103 | 97 |
| | HG-10 | | 11, 12 & 13 (2009) | 2 x RAP | 56 | 40 |
| Mid | HG-11 | HG-12 | 6 & 7 (2007) | 4 x REG | 70 | 64 |
| | HG-12 | | 16 & 17 (2007) | 4 x REG | 92 | 86 |
| | | | 10 & 11 (2008) | 2 x RAP | 49 | 49 |
| North | HG-14 | HG-17 | 35 & 36 (2006) | 3 x REG | 68 | 52 |
| | HG-16 | | 41 & 42 (2006) | 4 x REG | 87 | 71 |
| | HG-17 | | | | | |
| TOTAL | 13 | 5 | | 38 | 929 | 799 |

HG, Home Guard; No., number; RAP, Rapid Reaction; REG, Regular.

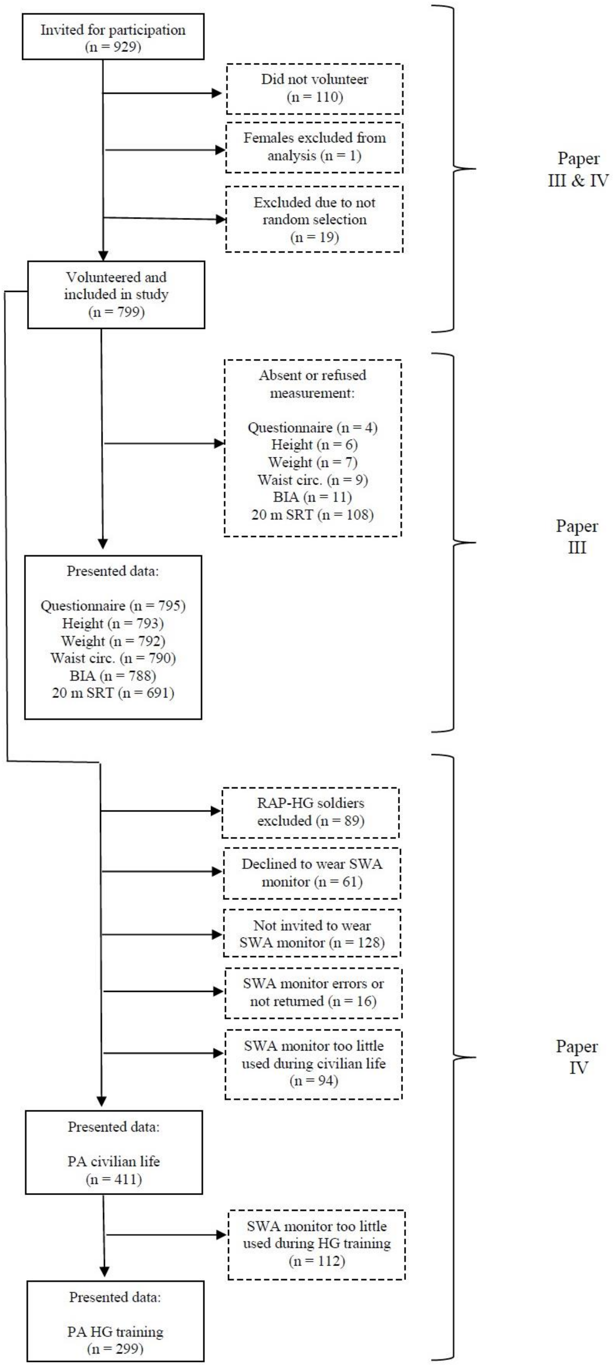


**Figure 3.** Flowchart detailing participation, exclusions and final presented data from the Moving Home Guard Soldiers Study. The upper section of the flowchart applies to both Paper III and IV. The middle section is specific to Paper III, while the lower section is specific to Paper IV.

20 m SRT, 20 meter shuttle run test; BIA, bioelectrical impedance analysis; HG, Home Guard; PA, physical activity; RAP, Rapid Reaction; REG, regular; SWA, SenseWear Armband.

## 2.3 Administration of data collection

In the Pilot – Cadet Development Study, the measurements were administered locally at the Air Force Academy in Trondheim, either in the sports hall (20 m SRT) or in a mobile test laboratory (all other measurements). The 20 m SRT was administered on day one, anthropometrical measurements and the treadmill familiarization trial on day two, while direct measurements of $\dot{V}O_{2max}$ took place on days three and four.

In the Body Composition Method Comparison Study, the DXA scans were conducted by trained staff at St. Olavs Hospital in Trondheim. The remaining measurements were administered at the Air Force Academy in Trondheim and at Ørland Main Air Station by three researchers; each responsible for the same measurements during the study (i.e. one person performed all the SKF measurements, another all the BIA measurements, etc.). All data were collected within three consecutive days for each subject. Twenty-four to 48 hours were allocated between test and retest measurements. Data were collected in the morning from 7 a.m. until noon. Prior to all measurements, the subjects followed a standardization strategy which included at least eight hours of fasting and no physical training, and at least two hours of no coffee or smoking. The subjects were allowed to drink water *ad libitum* prior to testing. Five of the women participated in the study during menstrual cycle. The temperature during all BIA and SKF measurements ranged between 19 and 21°C.

In the Moving Home Guard Soldiers Study, the five included HG districts were visited over a total of 11 HG training periods. At each visit, we typically informed the selected troops about the study at the beginning of the HG training week. The soldiers' measurements were carried out on the same day, or on a later day during the HG training. The tests were administered in sports halls at the garrison, and the majority of the soldiers wore sports attire during testing. Data collection occurred in the following sequence: a questionnaire was first handed out, then anthropometrical and body composition measurements were administered, followed by the 20 m SRT, and finally the physical activity monitors were distributed. Diet, fluid consumption and previous exercise were not standardized or restricted. Testing was administered from late morning to early evening, thus, different troops were tested at different times of the day.

Additional tests were administered for the subsample of HG soldiers who also volunteered for the 20 m SRT method comparison study (Paper I). On day one, these soldiers underwent the same tests as described above. Day two included a familiarization trial on the treadmill, while day three included the 20 m SRT retest. All of these tests took place at the garrison. One to two weeks after the end of the HG training, the soldiers carried out a direct $\dot{V}O_{2max}$ test in a mobile test laboratory placed at two locations near the HG soldiers' home area.

## 2.4 Procedures and measurements

An overview of the type of measurements included in the three studies is shown in Table 6. The test procedures are explained below. The tests were administered similarly in the different studies, unless stated otherwise.

**Table 6**. Types of measurements carried out in the three different studies included in this thesis.

| Measurements | Pilot – Cadet Development Study | Body Composition Method Comparison Study | Moving Home Guard Soldiers Study |
|---|---|---|---|
| Height and body weight | ● | ● | ● |
| WC | | | ● |
| SF-BIA | | ● | ● |
| MF-BIA | | ● | |
| SKF thickness | | ● | |
| DXA | | ● | |
| 20 m SRT | ● | | ● |
| Directly measured $\dot{V}O_{2max}$ | ● | | ○ |
| Objectively measured PA | | | ● |
| Questionnaire | | | ● |

20 m SRT, 20 meter shuttle run test; DXA, dual energy X-ray absorptiometry; MF-BIA, multi-frequency bioelectrical impedance analysis; PA, physical activity; SF-BIA, single frequency bioelectrical impedance analysis; SKF, skinfold; $\dot{V}O_{2max}$, maximal oxygen uptake; WC, waist circumference.
○ = administered to a sub-sample only; ● = administered to all subjects.

### 2.4.1 Height and body weight

A combined digital scale and stadiometer (model 708; SecaCorp., Hamburg, Germany) was used to measure height and body weight to the nearest 0.1 kg and 5 mm, respectively. Shoes were removed prior to measurement and 0.2–0.5 kg was subtracted since the subjects wore light clothing. The scale was calibrated with 40–80 kg weight plates (Eleiko Sport AB, Halmstad, Sweden) before start of each new test period. Body mass index was calculated by dividing body weight (in kilogram) by height (in meters) squared.

### 2.4.2 Waist circumference

Waist circumference (WC) was measured twice with a tape measure to the nearest 0.5 cm at the line of the umbilicus after a normal exhalation. The mean value of the two measurements was used in the analysis. If the two measurements differed more than 2.0 cm, a third or fourth measurement was conducted. The mean value of the two closest values was then used in the analysis.

### 2.4.3 Single frequency bioelectrical impedance analysis

The Quantum II (RJL Systems Inc., Clinton Township, MI, USA) body composition analyzer was used to measure SF-BIA (50 kHz). The device was calibrated once a day with a 500 ohm test resistor. Testing was carried out with the subjects lying supine on a mat and in a relaxed straight position. Socks and shoes were removed together with watch and jewelry on the right hand. Signal and detecting electrodes were attached on the right hand at the first joint of the middle finger and at an imaginary line bisecting the ulnar head, respectively. Similarly, the other signal and detecting electrodes were attached on the right foot at the base of the second/third toe and at a line bisecting the medial malleolus. The arms were positioned with approximately 30° between body and arms and the legs were positioned with approximately 0.5 m between the feet. The apparatus was then turned on and measurements were registered when resistance and reactance values had reached stable figures (after ca. 5–10 seconds). Fat free mass and skeletal muscle mass were calculated from the various SF-BIA equations summarized in Table 7. Body fat in kilogram was calculated from subtracting FFM from body weight, whereas percent BF was calculated from dividing BF (in kilogram) by body weight.

### 2.4.4 Multi-frequency bioelectrical impedance analysis

The InBody 720 (Biospace Co., Ltd., Seoul, Korea) apparatus was used to measure MF-BIA (1–1000 kHz). The subjects stepped on the foot electrodes barefoot and stood still until body weight was measured (subtracted 0.3 kg since subjects wore shorts and t-shirt). The subjects grasped the hand electrode cables, and gently held on to the thumb and palm electrode. Hands were held approximately 15° away from the body until measurements were completed. The inbuilt software was used to calculate percent BF and other body composition values.

### 2.4.5 Skinfold thickness

Skinfold thickness was measured with a Harpenden caliper (John Bull, British Indicators Ltd., West Sussex, UK) at seven sites for men (triceps, biceps, abdominal, suprailiac, thigh, subscapular and chest) and six sites for women (similar to men, excluding chest). Anatomical location of the sites was according to Heyward and Wagner[219] and Lohman et al.,[220] and always on the right side of the body. The sites were marked with a non-permanent marking pen, so that the sites had to be re-located for the retest. Two measurements were taken at each site. If the second measurement differed by more than 0.2 mm from the first reading, a third measurement was taken. The average of the two closest measurements was recorded. Nine different equations were used to calculate BD or percent BF (see Table 7). The equation by Siri[221] was used to calculate BF from BD: *BF (%) = (4.95/BD – 4.5) · 100*.

### 2.4.6 Dual-energy X-ray absorptiometry

Whole body DXA scans were performed using the Hologic Discovery A machine (Hologic Inc., Bedford, MA, USA) set at auto whole body fan beam mode. Results were analyzed using software version 12.7.3.1:3. The subjects removed jewelry and watch prior to the scan. Subjects were instructed to lie still on the DXA table during scanning, position their arms at their sides, extend their legs, and slightly rotate their feet inward. All subjects were tested once, except for 12 randomly chosen cadets (9 men and 3 women) who were re-scanned two days later to investigate test–retest reliability of the method.

### 2.4.7 20 meter shuttle run test

The 20 m SRT was conducted according to the protocol described by Léger et al.[78] The test leader visually demonstrated the test by running the first 3–4 shuttles, and explained how the test would proceed. Heart rate monitors (S 610; Polar Electro OY, Kempele, Finland) were then attached, and set at 5 seconds sampling rate. No warm-up was administered prior to the test. Three to twelve subjects ran the test together in each heat. The subjects ran back and forth between two lines 20 m apart, while running speed was dictated from compact disc audio bleeps. Initial speed was 8.5 km·h$^{-1}$ and increased by 0.5 km·h$^{-1}$ at every new level (approximately every minute). The number of shuttles in each level can be seen in Appendix 4. The subjects were instructed to pace themselves so that they reached the line concurrently with the signal (bleep). The test leader ran the first two levels together with the subjects, so that the pace was set correctly. For the individual subject, the test ended when he stopped running because of fatigue or when he was unable to reach the line on three consecutive occasions (≥ 3 m from the line). The peak HR stored on the monitor was written down. The subjects' running performance was registered as total shuttles achieved, the number of fully completed levels and the nearest last half level (LHL) achieved. For example, a subject who ran two shuttles at level 8 attained 8.0 LHL (a total of 62 shuttles), whereas a subject who ran seven shuttles into level 8 attained 8.5 LHL (a total of 67 shuttles). Maximal oxygen uptake was calculated from the equations shown in Table 7. All subjects' 20 m SRT results were included in the analysis. In the method comparison study (Paper I), the five existing 20 m SRT equations were selected because they were developed in samples of healthy adults (similar to our study sample). In Paper III, the aerobic fitness scores were described as $\dot{V}O_{2peak}$, since we were less sure that all subjects reached their true maximal effort during the test.

In the method comparison study, a blood sample was taken from the fingertip 3 minutes post test and analyzed for peak blood lactate concentration (1500 Sport; YSI Inc., Yellow Springs, Ohio, USA). This applied only to the HG soldiers and not the cadets (see Paper I). No blood lactate concentration was measured among the 691 HG soldiers reported in Paper III. Peak HR data from 54 (8 %) of the HG soldiers reported in Paper III were excluded due to assumed monitor interference or technical faults.

### 2.4.8 Directly measured maximal oxygen uptake (incl. familiarization trial)

Direct measurement of $\dot{V}O_{2max}$ included first a familiarization trial, then the real test on a subsequent day. The familiarization trial was conducted similarly to the real $\dot{V}O_{2max}$ test, except that the subjects stopped running 1–2 minutes before exhaustion. The aim of this trial was to familiarize the subjects to the $\dot{V}O_{2max}$ test protocol (including breathing in a mouthpiece), verify that all were able to run on a treadmill, and find an appropriate individual start speed for the $\dot{V}O_{2max}$ test.

The direct $\dot{V}O_{2max}$ test started with each subject completing a warm up procedure consisting of 15 minutes low-moderate intensity running, three bouts of 30 seconds high intensity running, followed by a few minutes of stretching. The subject then attached the nose clip and mouthpiece, the latter connected to a valve (model 2700, Hans Rudolf Inc., Kansas City, MO, USA). The test was performed on a treadmill (PPS 55 Sport, Woodway GmbH, Weil am Rhein, Germany) using a stepwise protocol with constant incline of 5.2 %. Initial running speed for the first minute was set individually according to previous performance in the 20 m SRT and the familiarization trial, so that fatigue would be expected to occur within 4–7 minutes of running. Treadmill speed was automatically increased by 1 $km{\cdot}h^{-1}$ every minute until volitional exhaustion. Peak HR was registered with a HR monitor (S 610; Polar Electro OY) set at 5 seconds sampling rate. Peak blood lactate concentration was measured from a blood sample taken from the fingertip three minutes post test and analyzed immediately (1500 Sport, YSI Inc.). The lactate analyzer was calibrated once every hour with a 5 $mmol{\cdot}L^{-1}$ lactate standard, and linearity was controlled with a 15 $mmol{\cdot}L^{-1}$ standard. Oxygen uptake was measured continuously with an online system (Oxycon Pro, Erich Jaeger GmbH, Hoechberg, Germany), using the mixing chamber mode set at 30 seconds sampling intervals. The average of the two highest consecutive measurements was defined as $\dot{V}O_{2max}$. The system was gas calibrated with room air and certified calibration gases, and volume calibrated manually with a 3 liter syringe (Hans Rudolf Inc.), before every second test (once every hour). The laboratory was supplied with adequate ventilation through air conditioning. The test was accepted if two of the following criteria were met: (1) peak HR

≥ 95 % of age predicted maximal HR (220 beats·min$^{-1}$ - age), (2) peak blood lactate concentration ≥ 7 mmol·L$^{-1}$, or (3) respiratory exchange ratio ≥ 1.10. All HG soldiers and cadets produced an accepted test.

### 2.4.9 Physical activity levels

The SenseWear Armband Pro2 (BodyMedia Inc., Pittsburgh, PA, USA) monitor was used to measure physical activity levels (Paper IV). The monitor was distributed to the HG soldiers immediately after they had carried out all other tests. They were instructed to wear the monitor for all remaining HG training days, and then for an additional seven consecutive civilian life days. Consequently, the number of days with the monitor worn during HG training varied among different troops. Some subjects were included in the study on the final day of their HG training, thus, no data during military training were obtained for these subjects. The subjects received thorough visual, oral and written explanations of how to use the monitor. The monitor was worn on the upper right arm at the triceps muscle and removed only during water activities. At the end of the measurement period the monitor was returned by pre-paid mail. The HG soldiers also returned a short questionnaire (Appendix 3) where they indicated which days they had worn the monitor during HG training and civilian life, if they had been more or less physically active than normal (including reasons for abnormality), and how much wear time they had during the period of monitoring.

The SenseWear Armband data were collected at 1 minute intervals and downloaded using Innerview Professional Software version 5.1 (BodyMedia Inc.). The software algorithms calculated values for several physical activity variables. Data for the following six variables were presented: TEE, number of steps, METs[222] and time in moderate (3–6 METs), vigorous (6–9 METs) and very vigorous (> 9 METs) intensity physical activity. A minimum of 20 hours of monitor wear time per day was treated as a valid day, while days with < 20 hours of wear time were excluded from the analysis. Inclusion criteria for an accepted civilian measurement period were at least two valid week days and one valid weekend day. Inclusion criteria for an accepted HG training measurement period were at least one valid HG training day (week day or weekend day) in addition to an accepted civilian measurement period. The day a soldier finished his HG training period and returned to civilian life was excluded from the analysis.

The SenseWear Armband monitor is classified as a multiple sensor system. We have previously validated this monitor (including the software version used in the present study) in civilian and military Norwegian adults.[179] Although some studies have demonstrated that the Armband monitor under or overestimated TEE and time in ≥ 3 METs, the monitor is generally considered to be valid and reliable and seems to compare favorably to alternative physical activity monitors.[179, 223-227]

#### 2.4.10 Questionnaire

In the Moving Home Guard Soldiers Study, the HG soldiers filled out a questionnaire while waiting for their turn to undertake the physical measurements. The questionnaire consisted of 63 items related to background information, physical activity levels, motivation towards exercising, etc. Except for questions related to gender, age, HG affiliation and military rank (question number 1, 2, 29, 31 and 32, see Appendix 3), the self-reported data are not included in the present thesis.

**Table 7**. Overview of prediction equations used in the four papers of the present thesis.

| Paper | Method | Reference | Prediction equation |
|---|---|---|---|
| 1 | 20 m SRT | Léger et al.[78] | $\dot{V}O_{2max} = -24.4 + 6 \cdot MAS$ |
| | | Ramsbottom et al.[81] | N/A (prediction table displayed at pp. 144 in article[81]) |
| | | Léger & Gadoury[84] | $\dot{V}O_{2max} = -32.678 + 6.592 \cdot MAS$ |
| | | Stickland et al.[79] | $\dot{V}O_{2max} = 2.75 \cdot X + 28.8$ |
| | | Flouris et al.[228] | $\dot{V}O_{2max} = (MAS \cdot 6.65 - 35.8) \cdot 0.95 + 0.182$ |
| | | Aandstad et al.[229] | $\dot{V}O_{2max} = 2.71 \cdot X + 26.5$ |
| 2 | SKF | Durnin & Womersley[230] (m) | $BD = 1.1765 - 0.0744 \cdot \log \Sigma 1$ |
| | | Durnin & Womersley[230] (w) | $BD = 1.1567 - 0.0717 \cdot \log \Sigma 1$ |
| | | Jackson & Pollock[231] (m) | $BD = 1.1125025 - 0.0013125 \cdot \Sigma 2 + 0.0000055 \cdot \Sigma 2^2 - 0.0002440 \cdot A$ |
| | | Jackson & Pollock[231] (w) | $BD = 1.089733 - 0.0009245 \cdot \Sigma 3 + 0.0000025 \cdot \Sigma 3^2 - 0.0000979 \cdot A$ |
| | | Jackson et al.[232] (m) | $BF = 0.2568 \cdot \Sigma 4 - 0.0004 \cdot \Sigma 4^2 + 4.8647$ |
| | | Jackson et al.[232] (w) | $BF = 0.4446 \cdot \Sigma 4 - 0.0012 \cdot \Sigma 4^2 + 4.3387$ |
| | | Lohman[120] (m) | $BD = 1.0982 - 0.000815 \cdot \Sigma 5 + 0.00000084 \cdot \Sigma 5^2$ |
| | | Slaughter et al.[233] (m) | $BF = 1.21 \cdot \Sigma 6 - 0.008 \cdot \Sigma 6^2 - 5.5$ |
| | | Slaughter et al.[233] (w) | $BF = 1.33 \cdot \Sigma 6 - 0.013 \cdot \Sigma 6^2 - 2.5$ |
| | SF-BIA | Deurenberg et al.[234] (m + w) | $FFM = 0.340 \cdot H^2/R - 0.127 \cdot A + 0.273 \cdot BW + 4.56 \cdot G1 + 0.1534 \cdot H - 12.44$ |
| | | Gray et al.[235] (m) | $FFM = 0.00139 \cdot H^2 - 0.0801 \cdot R + 0.187 \cdot BW + 39.830$ |
| | | Gray et al.[235] (w) | $FFM = 0.00151 \cdot H^2 - 0.0344 \cdot R + 0.140 \cdot BW - 0.158 \cdot A + 20.387$ |
| | | Kotler et al.[236] (m) | $FFM = 0.50 \cdot (H^{1.48}/R^{0.55}) \cdot (1.0/1.21) + 0.42 \cdot BW + 0.49$ |
| | | Kotler et al.[236] (w) | $FFM = 0.88 \cdot (H^{1.97}/R^{0.49}) \cdot (1.0/22.22) + 0.081 \cdot BW + 0.07$ |
| | | Kyle et al.[237] (m + w) | $FFM = 0.518 \cdot H^2/R + 0.231 \cdot BW + 0.130 \cdot Xc + 4.229 \cdot G1 - 4.104$ |
| | | Lohman[119] (m) | $FFM = 0.485 \cdot H^2/R + 0.338 \cdot BW + 5.32$ |
| | | Lohman[119] (w) | $FFM = 0.476 \cdot H^2/R + 0.295 \cdot BW + 5.49$ |
| | | Lukaski et al.[238] (m) | $FFM = 0.827 \cdot H^2/R + 5.214$ |
| | | Lukaski et al.[238] (w) | $FFM = 0.821 \cdot H^2/R + 4.917$ |
| | | Segal et al. GEN[239] (m) | $FFM = 0.00132 \cdot H^2 - 0.04394 \cdot R + 0.30520 \cdot BW - 0.16760 \cdot A + 22.66827$ |
| | | Segal et al. GEN[239] (w) | $FFM = 0.00108 \cdot H^2 - 0.02090 \cdot R + 0.23199 \cdot BW - 0.06777 \cdot A + 14.59453$ |
| | | Segal et al. FSE[239] (m) | $FFM = 0.0006636 \cdot H^2 - 0.02117 \cdot R + 0.62854 \cdot BW - 0.12380 \cdot A + 9.33285$ |
| | | Segal et al. FSE[239] (w) | $FFM = 0.00064602 \cdot H^2 - 0.01397 \cdot R + 0.42087 \cdot BW + 10.43485$ |
| | | Sun et al.[240] (m) | $FFM = 0.65 \cdot H^2/R + 0.26 \cdot BW + 0.02 \cdot R - 10.68$ |
| | | Sun et al.[240] (w) | $FFM = 0.69 \cdot H^2/R + 0.17 \cdot BW + 0.02 \cdot R - 9.53$ |
| | | van Loan et al.[241] (m + w) | $FFM = 0.51 \cdot H^2/R + 0.33 \cdot BW + 1.69 \cdot G2 + 3.66$ |
| | SKF & SF-BIA | Guo et al.[242] (m) | $BF = -0.2790 \cdot H^2/R + 0.6316 \cdot T + 0.3464 \cdot BW + 1.5034$ |
| | | Yannakoulia et al.[243] (w) | $FFM = 0.391 \cdot BW + 0.168 \cdot H - 0.253 \cdot T + 0.144 \cdot H^2/R - 9.49$ |
| | MF-BIA | InBody 720 (m + w) | Equation not released by manufacturer (in-built equation used) |
| 3 | SF-BIA | Sun et al.[240] | $FFM = 0.65 \cdot H^2/resistance + 0.26 \cdot BW + 0.02 \cdot resistance - 10.68$ |
| | | Janssen et al.[244] | $SMM = 0.401 \cdot height^2/resistance + 3.825 - 0.071 \cdot A + 5.102$ |
| | 20 m SRT | Aandstad et al.[229] | $\dot{V}O_{2peak} = 2.71 \cdot X + 26.5$ |
| 4 | PA | BodyMedia Inc. | Equations not released by manufacturer (Innerview v. 5.1) |

20 m SRT, 20 meter shuttle run test; A, age (years); BD, body density; BF, body fat (%); BW, body weight (kg); FFM, fat free mass; FSE, fatness specific equation; G1, gender (man = 1, woman = 0); G2, gender (man = 1, woman = -1); GEN, generalized equation; H, height (cm); m, men; MAS, maximal aerobic speed; MF-BIA, multi-frequency bioelectrical impedance analysis; N/A, not available; PA, physical activity; R, resistance (ohm); SF-BIA, single frequency bioelectrical impedance analysis; SKF, skinfold; SMM, skeletal muscle mass; T, triceps SKF (mm); $\dot{V}O_{2max}$, maximal oxygen uptake; $\dot{V}O_{2peak}$, peak oxygen uptake; w, women; X, last half level; Xc, reactance (ohm); Σ1, sum of triceps + biceps + subscapular + suprailiac SKF (mm); Σ2, sum of chest + triceps + subscapular SKF (mm); Σ3, sum of triceps + suprailiac + abdominal SKF (mm); Σ4, sum of triceps + suprailiac + thigh SKF (mm); Σ5, sum of triceps + abdominal + subscapular SKF (mm); Σ6, sum of triceps + subscapular SKF (mm).

## 2.5 Statistics

All outcome variables (including residuals) were checked for normality by visual inspections of data distribution plots. All data were considered and treated as normally distributed, except for three physical activity variables in Paper IV: time in moderate, vigorous and very vigorous intensity physical activity. Data for these variables were skewed in addition to including values of zero, thus, square-root transformations were performed prior to analyzing these data for differences between conditions. Transformed data were subsequently back-transformed before being presented.

In Papers I and II, we investigated test–retest reliability and criterion-related validity. Results were expressed by mean difference ± 95 % LoA, ICC (3,1 – single measures), Pearson correlation coefficient *r* and coefficient of variation (CV, in percent, calculated as the mean CV from individual CVs). Data from the first test were always used to evaluate validity. Mean difference between test and retest, and between the criterion-related method and indirect methods were analyzed with a paired samples *t* test. Differences between groups (e.g. men vs. women) were analyzed with an independent samples *t* test. In Paper I, we created a new 20 m SRT prediction equation from a simple linear regression model with measured $\dot{V}O_{2max}$ as the dependent variable. The independent variables (age, height, peak HR and 20 m SRT performance) were excluded in a stepwise fashion if they did not reach the significance level ($P < 0.05$).

In Papers III and IV, a linear mixed-effect model with the restricted maximum likelihood approach and least significant difference (LSD) confidence interval (CI) adjustments was used to check for differences between groups. The mean difference between groups was based on estimated marginal means. The mixed model allowed us to account for the cluster-randomized design, using troop as a random effect. Analyses in Paper III were always adjusted for age and HG district when checking for differences between groups. In addition, we adjusted for military rank when assessing differences between REG-HG and RAP-HG personnel and we adjusted for HG force when checking for differences between officers and private soldiers. In Paper IV, data from the same individuals were compared over different time points (civilian life vs. HG training); thus, these data were analyzed as repeated measurements.

All descriptive data were presented as mean with 95 % CI or SD if not otherwise stated, except for the skewed data in Paper IV which were presented as median with $25^{th}$–$75^{th}$ percentiles. In Papers III and IV, we also presented descriptive data as cumulative relative frequency (percent). A chi-squared test was used to examine differences in frequencies between REG-HG and RAP-HG soldiers.

Statistical analyses were performed in SPSS version 15, 18 or 21 (IBM Corporation, Armonk, NY, USA), in MedCalc version 11.1 or 12.1 (MedCalc Software bvba, Ostend, Belgium) or with Graphpad version Prism 5 (Graphpad Software Inc., La Jolla, CA, USA). Probability (*P*) values of < 0.05 were considered statistically significant.

# 3 RESULTS

This chapter includes presentation of the main results of the four papers included in this thesis.

## 3.1 Reliability and validity of the 20 meter shuttle run test (Paper I)

**Reliability**

The 41 HG soldiers completed on average 2.7 more shuttles in the retest compared to the first 20 m SRT trial (*P* = 0.002), while the 95 % LoA demonstrated a measurement error of ± 10.1 shuttles (Figure 4A). Expressed as estimated $\dot{V}O_{2max}$ (based on our LHL-equation, see below), this corresponds to a bias ± 95 % LoA of -0.8 ± 3.1 mL·kg$^{-1}$·min$^{-1}$. Pearson *r*, ICC (95 % CI) and CV were 0.96, 0.96 (0.93, 0.98) and 5.3 %, respectively, for total number of shuttles completed in test and retest.

**Validity**

In step one of the validity process, we developed new equations for predicting $\dot{V}O_{2max}$ from the 20 m SRT based on data collected on 38 REG-HG soldiers. The two best prediction equations were based on LHL and total shuttles:

$\hat{Y} = 2.71X + 26.5$ ($\hat{Y}$; predicted $\dot{V}O_{2max}$ in mL·kg$^{-1}$·min$^{-1}$, X; the LHL completed in the 20 m SRT).

$\hat{Y} = 0.265X + 31.5$ ($\hat{Y}$; predicted $\dot{V}O_{2max}$ in mL·kg$^{-1}$·min$^{-1}$, X; number of completed shuttles in the 20 m SRT).

Both equations explained 67 % (*r* = 0.82, *P* < 0.001) of the variance in directly measured $\dot{V}O_{2max}$, and generated a 95 % LoA of ± 7.2 mL·kg$^{-1}$·min$^{-1}$ between directly measured and estimated $\dot{V}O_{2max}$ in the 38 HG soldiers. Figure 4B shows the relationship between $\dot{V}O_{2max}$ measured directly and 20 m SRT performance (expressed as LHL).

In step two, we cross-validated our LHL-based equation and five alternative equations (see Table 7) on 28 cadets. There was no significant mean difference between estimated and directly measured $\dot{V}O_{2max}$ for our new equation, the Léger et al. equation and the Léger and Gadoury equation. The Ramsbottom et al. equation and the Flouris et al. equation underestimated $\dot{V}O_{2max}$ by 5.6–5.7 mL·kg$^{-1}$·min$^{-1}$ (*P* < 0.001), while the equation given by Stickland et al. overestimated $\dot{V}O_{2max}$ by 2.4 mL·kg$^{-1}$·min$^{-1}$ (*P* < 0.001). The 95 % LoA ranged between ± 6.2 and ± 6.4 mL·kg$^{-1}$·min$^{-1}$ for all six equations, and *r* ranged from 0.67 to 0.69. Cadets with lower aerobic fitness seemed to have their $\dot{V}O_{2max}$ overestimated (Figure 4C); a pattern that was seen in all of the six prediction equations scrutinized. However, this pattern was not evident when data from HG soldiers and cadets were combined (Figure 4D). The combined data produced a Pearson correlation coefficient between estimated and directly measured $\dot{V}O_{2max}$ of $r$ = 0.85 ($P$ < 0.001).

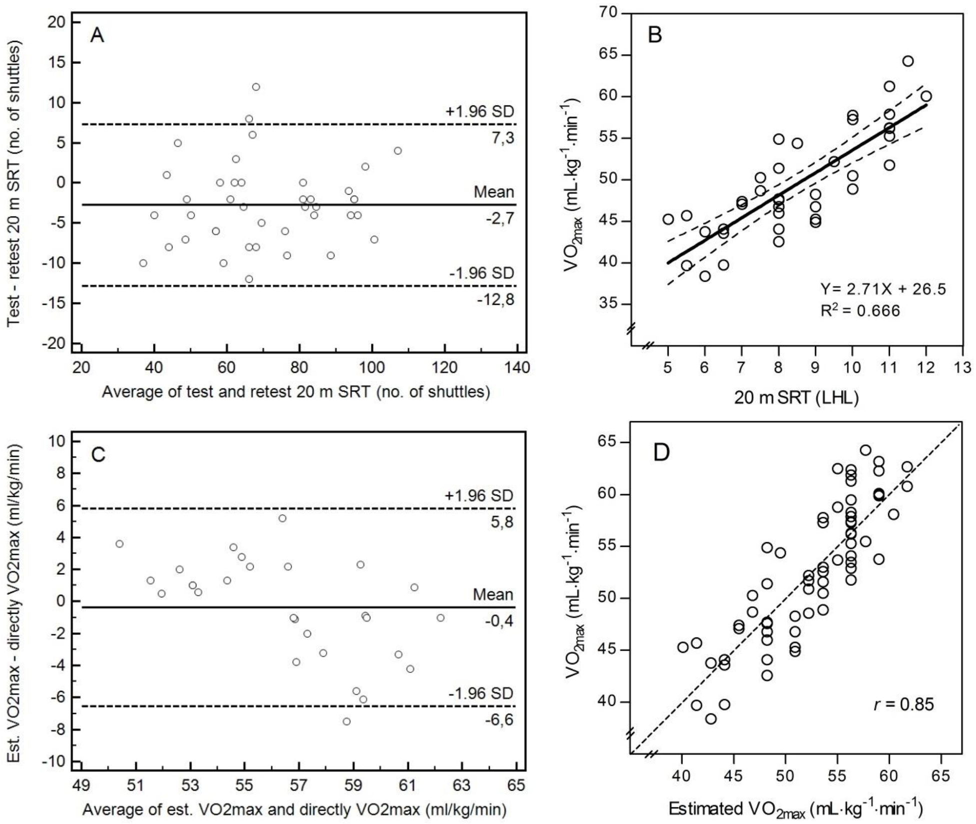


**Figure 4**. **A**: Bland-Altman plot with 95 % limits of agreement for test and retest 20 m SRT performance (number of shuttles) in 41 Home Guard soldiers. **B**: Scatterplot of the relationship between directly measured maximal oxygen uptake ($\dot{V}O_{2max}$) and 20 m SRT performance, expressed as last half level (LHL) in 38 Home Guard soldiers. The regression line includes 95 % confidence interval for the line (mean). **C**: Bland-Altman plot with 95 % limits of agreement for estimated $\dot{V}O_{2max}$ from the 20 m SRT with our new LHL-equation against directly measured $\dot{V}O_{2max}$ in 28 cadets. **D**: Scatterplot of the relationship between directly measured and estimated $\dot{V}O_{2max}$ from our new LHL-equation, in 38 Home Guard soldiers and 28 cadets combined (n = 66). Dashed line = line of identity.

## 3.2 Reliability and validity of field methods to predict body fat (Paper II)

**Reliability**

Descriptive body composition data at test and retest are presented in Paper II, along with complete tables pertaining to reliability for all of the equations scrutinized. A truncated table is given in Table 8. For both men and women, the best SF-BIA equations produced narrower LoA and smaller CV (higher reliability) compared to the other field methods. For both men and women, the lowest ICC values were produced by SKF equations, indicating lower reliability for the SKF method compared to the other methods. In men, all SKF equations predicted percent BF to be significantly higher in the retest compared to the first test.

Test–retest reliability for DXA was measured in cadets (9 men and 3 women). Mean difference ± 95 % LoA was −0.1 ± 0.8 % BF, ICC was 0.998 (0.992 – 0.999), whereas CV was 1.2 %.

**Table 8**. Test–retest reliability statistics for predicted percent body fat from SKF and BIA measurements in 39 men and 26 women. For SKF and SF-BIA, only the two equations with the narrowest and widest 95 % LoA are presented (see Paper II for complete tables).

| Gender | Method | Equation | Mean difference ± 95 % LoA | ICC (95 % CI) | CV (%) |
|---|---|---|---|---|---|
| Men | SKF | Jackson & Pollock[231] | -0.4 ± 1.3* | 0.98 (0.96, 0.99) | 3.6 |
| | | Durnin & Womersley[230] | -1.4 ± 3.5* | 0.91 (0.84, 0.95) | 5.3 |
| | SF-BIA | Segal et al. FSE[239] | 0 ± 0.7 | 0.99 (0.98, 0.99) | 1.4 |
| | | Lukaski et al.[238] | 0 ± 3.6 | 0.96 (0.93, 0.98) | 6.6 |
| | SKF & SF-BIA | Guo et al.[242] | -0.3 ± 1.4* | 0.99 (0.98, 0.99) | 2.8 |
| | MF-BIA | InBody 720 equation | -0.1 ± 2.3 | 0.97 (0.94, 0.98) | 5.1 |
| Women | SKF | Slaughter et al.[233] | -0.1 ± 2.0 | 0.96 (0.90, 0.98) | 1.9 |
| | | Jackson et al.[232] | 0.1 ± 4.2 | 0.92 (0.83, 0.96) | 4.0 |
| | SF-BIA | Segal et al. FSE[239] | -0.1 ± 0.8 | 0.99 (0.99, 1.00) | 0.9 |
| | | Lukaski et al.[238] | -0.3 ± 2.8 | 0.98 (0.96, 0.99) | 3.2 |
| | SKF & SF-BIA | Yannakoulia et al.[243] | 0 ± 1.8 | 0.99 (0.97, 0.99) | 1.8 |
| | MF-BIA | InBody 720 equation | 0.2 ± 2.6 | 0.98 (0.95, 0.99) | 3.4 |

BIA, bioelectrical impedance analysis; CI, confidence interval; CV, coefficient of variation; FSE, fatness specific equation; ICC, intraclass correlation coefficient; LoA, limits of agreement; MF, multi-frequency; SF, single frequency; SKF, skinfold.
* $P < 0.05$ for mean difference between test and retest.

**Validity**

Complete tables pertaining to validity for all the equations scrutinized in men and women are presented in Paper II, while a truncated table is shown in Table 9. In men, the SF-BIA method generally produced wider LoA and lower *r* against DXA (lower validity) than the other methods. All methods, except for the SF-BIA method, produced LoA values below 4.0 % against DXA. The combined SF-BIA and SKF equation produced the highest *r* values against DXA (Figure 5A), while the Jackson et al. SKF equation produced the narrowest LoA. There was a significant mean difference between estimated and DXA-measured percent BF in all but two SF-BIA equations. In women, some of the SF-BIA equations produced the narrowest LoA among all methods and equations (Table 9 and Paper II). Yet, other SF-BIA equations produced the widest LoA. The MF-BIA device produced the highest *r* against DXA (Figure 5B), but the inbuilt equation underestimated BF by about 2 percentage points, as also observed in men. There was a significant mean difference between estimated and DXA-measured percent BF in all but one SKF equation and four SF-BIA equations, and an over-estimation of BF by 6.6 percentage points was demonstrated in one of the SKF equations.

**Table 9**. Validity statistics for predicted percent BF from SKF and BIA measurements against percent BF measured with DXA in 39 men and 26 women. For SKF and SF-BIA, only the two equations with the narrowest and widest LoA are presented (see Paper II for complete tables).

| **Gender** | **Method** | **Equation** | **Mean diff. ± 95 % LoA (BF %)** | **Pearson *r*** | ***P* value for mean diff.** |
|---|---|---|---|---|---|
| Men | SKF | Jackson et al. [232] | -0.9 ± 3.5 | 0.88 | 0.002 |
| | | Slaughter et al. [233] | 1.6 ± 5.2 | 0.87 | 0.001 |
| | SF-BIA | Kotler et al. [236] | 2.2 ± 4.4 | 0.81 | < 0.001 |
| | | Lukaski et al. [238] | 2.9 ± 8.5 | 0.82 | < 0.001 |
| | SKF & SF-BIA | Guo et al. [242] | 0.6 ± 3.6 | 0.92 | 0.039 |
| | MF-BIA | InBody 720 equation | -2.1 ± 3.9 | 0.90 | < 0.001 |
| Woman | SKF | Jackson & Pollock [231] | 2.3 ± 4.7 | 0.88 | < 0.001 |
| | | Durnin & Womersley [230] | 6.6 ± 6.6 | 0.88 | < 0.001 |
| | SF-BIA | Kyle et al. [237] | 2.5 ± 4.0 | 0.92 | < 0.001 |
| | | Lukaski et al. [238] | 0.9 ± 8.0 | 0.90 | 0.245 |
| | SKF & SF-BIA | Yannakoulia et al. [243] | 1.8 ± 5.3 | 0.86 | 0.002 |
| | MF-BIA | InBody 720 equation | -1.9 ± 5.2 | 0.93 | 0.001 |

BF, body fat; BIA, bioelectrical impedance analysis; diff., difference; DXA, dual-energy X-ray absorptiometry; LoA, limits of agreement; MF, multi-frequency; SF, single frequency; SKF, skinfold.

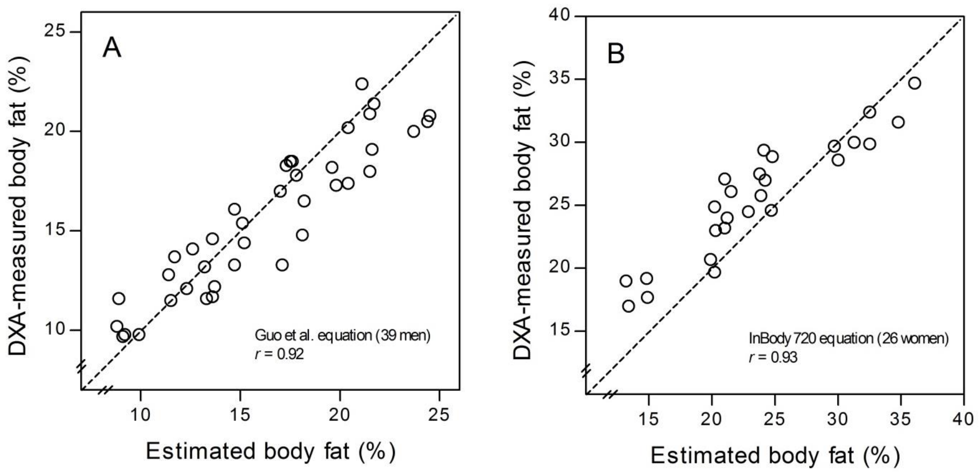


**Figure 5**. Scatterplots of the relationship between percent body fat measured by dual-energy X-ray absorptiometry (DXA) and two selected field methods. Figure **A** and **B** show the field methods that produced the highest Pearson *r* against DXA in men and women, respectively. Dashed line = line of identity.

## 3.3 Physical fitness in Home Guard soldiers (Paper III)

**Anthropometrics and body composition**

Anthropometrical data and body composition are presented separately for REG-HG and RAP-HG soldiers in Table 10. The RAP-HG soldiers had significantly lower BF and higher skeletal muscle mass compared to REG-HG soldiers. Among REG-HG soldiers, 13 % had a BMI ≥ 30 $kg \cdot m^{-2}$, while the corresponding number was 9 % among RAP-HG soldiers. If dividing the subjects into officers and private soldiers, no significant differences in any of the anthropometrical or body composition variables were evident. The cumulative relative frequency for selected anthropometrical and body composition variables can be seen in Paper III.

**Table 10**. Anthropometrics and body composition in REG-HG and RAP-HG soldiers. Values are mean (95 % CI).

| Variable | REG-HG (n = 700–704) | RAP-HG (n = 88–89) | Adj. diff. | *P* value |
|---|---|---|---|---|
| Height (cm) | 180.0 (179.5, 180.5) | 181.5 (180.0, 183.0) | 0 (-2.0, 2.5) | 0.830 |
| Body weight (kg) | 85.0 (84.0, 85.9) | 83.9 (80.9, 87.0) | 0 (-3.7, 3.6) | 0.979 |
| BMI ($kg \cdot m^{-2}$) | 26.2 (25.9, 26.4) | 25.4 (24.7, 26.2) | -0.1 (-1.1, 0.8) | 0.772 |
| WC (cm) | 94.5 (94.0, 95.5) | 91.5 (89.5, 93.5) | -1.5 (-4.0, 1.5) | 0.301 |
| FFM (kg) | 67.5 (66.9, 68.1) | 68.9 (66.9, 70.8) | 2.2 (-0.1, 4.4) | 0.057 |
| BF (kg) | 17.5 (17.0, 18.0) | 14.9 (13.3, 16.4) | -2.4 (-4.4, -0.4) | 0.021 |
| BF (%) | 20.0 (19.6, 20.4) | 17.2 (16.0, 18.3) | -2.9 (-4.5, -1.3) | 0.001 |
| SMM (kg) | 35.6 (35.3, 35.9) | 37.1 (36.3, 38.0) | 1.6 (0.6, 2.7) | 0.001 |

Adj. diff., adjusted difference; BF, body fat; BMI, body mass index; CI, confidence interval; FFM, fat-free mass; HG, Home Guard; REG, Regular; RAP, Rapid Reaction; SMM, skeletal muscle mass; WC, waist circumference.
Differences are adjusted for age, HG district, and military rank, and reflect RAP-HG minus REG-HG.

**Aerobic fitness**

691 HG soldiers ran the 20 m SRT, and the mean (95 % CI) number of shuttles completed was 70 (69, 72). The corresponding estimated $\dot{V}O_{2peak}$ (using our new LHL prediction equation) was 50.1 (49.7, 50.6) $mL \cdot kg^{-1} \cdot min^{-1}$. 20 m SRT results are presented separately for REG-HG and RAP-HG soldiers in Table 11. No significant difference in running performance was observed between the two HG forces, after adjusting for differences in age, HG district and military rank. When categorizing the subjects according to military rank, HG officers achieved a 2.2 (0.9, 3.5) $mL \cdot kg^{-1} \cdot min^{-1}$ higher estimated $\dot{V}O_{2peak}$ compared to HG private soldiers ($P$ = 0.001). The cumulative relative frequencies for total number of shuttles and estimated $\dot{V}O_{2peak}$ for REG-HG and RAP-HG soldiers combined are shown in Figure 6.

**Table 11**. Aerobic fitness from the 20 meter shuttle run test in REG-HG and RAP-HG soldiers. Values are means (95 % CI).

| Variable | REG-HG (n = 614) | RAP-HG (n = 77) | Adj. diff. | *P* value |
|---|---|---|---|---|
| Total shuttles (no.) | 69 (68, 71) | 78 (74, 83) | 3 (-4, 10) | 0.401 |
| LHL (no.) | 8.5 (8.5, 9.0) | 9.5 (9.0, 10.0) | 0 (-0.5, 1.0) | 0.478 |
| $\dot{V}O_{2peak}$ (mL·kg$^{-1}$·min$^{-1}$) | 49.9 (49.4, 50.3) | 52.1 (51.0, 53.3) | 0.7 (-1.2, 2.5) | 0.475 |
| Peak HR (beats·min$^{-1}$) | 190 (189, 191) | 192 (189, 194) | 0 (-4, 3) | 0.972 |

Adj. diff., adjusted difference; CI, confidence interval; HG, Home Guard; HR, heart rate; LHL, last half level; no., number; RAP, Rapid Reaction; REG, Regular; $\dot{V}O_{2peak}$, peak oxygen uptake.
Differences are adjusted for age, HG district, and military rank, and reflect RAP-HG minus REG-HG.

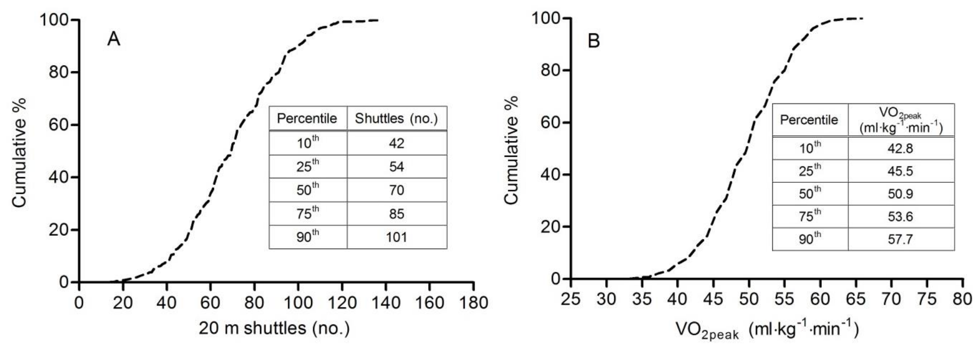


**Figure 6**. Cumulative relative frequency (percent) for number of shuttles **(A)** and estimated peak oxygen uptake **(B)** from the 20 meter shuttle run test in 691 Home Guard soldiers.

## 3.4 Physical activity in Home Guard soldiers (Paper IV)

**Physical activity during civilian life**

411 REG-HG soldiers produced accepted physical activity data during civilian life. Five out of six physical activity variables were significantly higher during week days compared to weekend days (Table 12). The median time spent in ≥ moderate intensity physical activity from the weighted mean of civilian week days and weekend days was almost 3 hours (179 minutes) per day. This includes 4 minutes per day with very vigorous physical activity (> 9 METs). The cumulative relative frequencies of the six variables (weighted mean of civilian week days and weekend days) can be seen in Paper IV.

**Table 12**. Physical activity characteristics during civilian week days (Monday – Friday) and weekend days (Saturday – Sunday) in 411 Home Guard soldiers.

| Variable | Week | Weekend | Difference | *P* value |
|---|---|---|---|---|
| TEE (kcal) | 3548 (3472, 3623) | 3382 (3309, 3454) | 166 (64, 268) | 0.001 |
| Steps (no.) | 10448 (10037, 10859) | 9209 (8780, 9638) | 1251 (628, 1874) | < 0.001 |
| METs | 1.78 (1.74, 1.82) | 1.70 (1.66, 1.74) | 0.08 (0.03, 0.13) | 0.002 |
| Moderate PA (min.) | 153 (105–239) | 140 (93–209) | 21 | 0.001 |
| Vigorous PA (min.) | 17 (8–33) | 15 (5–29) | 2 | 0.053 |
| Very vigorous PA (min.) | 3 (1–8) | 2 (0–7) | 1 | 0.029 |

kcal, kilocalories; METs, metabolic equivalents; min., minutes; no., number; PA, physical activity; TEE, total energy expenditure.
TEE, steps and METs are presented as mean (95 % confidence intervals, CI) per day, while the other variables are presented as median ($25^{th}$-$75^{th}$ percentiles). Differences are based on estimated marginal means from the linear mixed-effect model, and reflect week days minus weekend days. The 95 % CI, with the CIs adjusted for the cluster sampling, are only given for TEE, steps and METs.

**Physical activity during military training**

299 REG-HG soldiers produced accepted physical activity data during HG military training. Mean (95 % CI) TEE, steps and METs during HG training were 3540 (3472, 3609) kcal, 10645 (10304, 10985) steps and 1.76 (1.73, 1.79) METs, respectively. Median (25–$75^{th}$ percentiles) times spent in moderate, vigorous and very vigorous physical activity during HG training were 186 (141–241) minutes, 11 (5–18) minutes and 1 (0–4) minutes, respectively.

The HG soldiers spent significantly more time in moderate intensity physical activity during HG training compared to civilian life, but less time in vigorous and very vigorous physical activity. There were no differences in mean TEE, steps or METs between HG training days and civilian life days. Figure 7 displays the differences in moderate and very vigorous physical activity during HG training and civilian life, while a complete set of figures can be seen in Paper IV. Drop-out analyses are also presented in Paper IV.

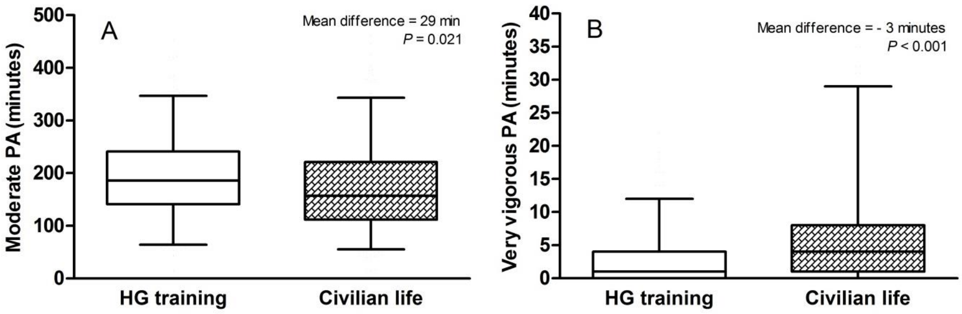


**Figure 7**. Moderate **(A)** and very vigorous **(B)** physical activity (PA) levels in 299 Home Guard (HG) soldiers during HG military training and civilian life, respectively. The data from civilian life represent weighted mean of week days and weekend days combined (average per day). The boxes cover the range from 25$^{th}$ to 75$^{th}$ percentile, the whiskers cover the range from 5$^{th}$ to 95$^{th}$ percentile, while the horizontal line in the box indicate median.

# 4 DISCUSSION

This chapter begins with a general discussion of the main findings in light of existing studies in the field. Thereafter, methodological considerations are discussed, followed by reflections regarding implications of the study, recommendations and future study perspectives.

## 4.1 General discussion of main results

### 4.1.1 Reliability and validity of the 20 meter shuttle run test (Paper I)

Our reliability analysis of the 20 m SRT demonstrated a test–retest 95 % LoA of ± 10.1 shuttles (or ± 3.1 $mL·kg^{-1}·min^{-1}$) in HG soldiers. Two previous studies of adult civilians reported wider test–retest LoA for the 20 m SRT compared to our findings,[245, 246] while a third study demonstrated slightly narrower LoA.[80] Hence, our data on reliability appear to be in the same range, or somewhat better, compared to previous studies. The HG soldiers ran 2.7 more shuttles in the retest compared to the first test. The slightly better retest performance was probably due to test habituation, and is in accordance with two previous studies.[245, 246] While Lamb et al.[245] demonstrated an increase in performance between the test and retest, they also concluded that no further increase was evident between a second and a third trial. In a third study, Cooper et al.[80] did not find a significant test–retest bias, but their reliability study was conducted on sports students accustomed to the 20 m SRT. Thus, it seems that one pre-test is necessary to obtain stable measurements in adults unfamiliar with the test. It should be pointed out that the bias between a first and second trial on unaccustomed subjects appears to small, and its practical meaningfulness has been questioned.[245] While some concluded that the 20 m SRT is reliable,[78, 80, 247] others drew attention to the rather wide test–retest LoA.[245, 246] The different conclusions may be related to different analytical goals, as there is no universal agreement of what is acceptable reliability, and the tolerable measurement error may vary depending on the purpose of the test.[56, 245] For soldiers in general, a test–retest measurement error of about ± 3 $mL·kg^{-1}·min^{-1}$ seems tolerable, as this corresponds to a relatively small measurement error of 5–7 % in aerobic fitness level for an average fit male soldier.

Validity of the 20 m SRT was first checked against directly measured $\dot{V}O_{2max}$ in HG soldiers (step one). In step two, the HG-generated prediction equation was cross-validated on cadets. Pearson correlations between estimated and measured $\dot{V}O_{2max}$ were $r$ = 0.82, 0.69 and 0.85 in HG soldiers, cadets, and the two groups combined, respectively. A recent meta-analysis including 48 validation studies of the 20 m SRT reported a mean $r$ = 0.77 between performance in the 20 m SRT and directly measured $\dot{V}O_{2max}$.[248] Accordingly, our correlation coefficients appear to be within the same range as found in other studies. Yet, it may be difficult to compare *r* values among different studies, since correlation coefficients are influenced by the variance within the samples studied.[216] In this regard, the 95 % LoA may be a preferable statistical method.[216] In HG soldiers, the 95 % LoA between estimated and measured $\dot{V}O_{2max}$ was ± 7.2 mL·kg$^{-1}$·min$^{-1}$, while the corresponding figure was ± 6.2 mL·kg$^{-1}$·min$^{-1}$ in cadets with our new prediction equation. By comparison, Olander[85] reported a 95 % LoA of ± 5.2 mL·kg$^{-1}$·min$^{-1}$ (and $r$ = 0.96) between estimated and measured $\dot{V}O_{2max}$, using a slightly modified 20 m SRT. Olander's study included 43 adult Swedish male and female military personnel. Previous studies on civilian adults reported 95 % LoA of 6.2–7.4 mL·kg$^{-1}$·min$^{-1}$[80, 246, 247, 249] and standard error of the estimates of 3.0–4.7 mL·kg$^{-1}$·min$^{-1}$.[78, 79, 81, 84, 250, 251] Since our study demonstrated a LoA of about 7 mL·kg$^{-1}$·min$^{-1}$, this means that a true directly measured $\dot{V}O_{2max}$ of for example 50 mL·kg$^{-1}$·min$^{-1}$ may be estimated to anywhere between 43 and 57 mL·kg$^{-1}$·min$^{-1}$ in the 20 m SRT. Although it is likely that a soldier with an estimated $\dot{V}O_{2max}$ of 57 mL·kg$^{-1}$·min$^{-1}$ has a higher directly measured $\dot{V}O_{2max}$ compared to a fellow soldier estimated at 43 mL·kg$^{-1}$·min$^{-1}$, we cannot really be certain. Paper III in this thesis showed that 523 out of 691 HG soldiers (76 %) tested on the 20 m SRT had an estimated $\dot{V}O_{2max}$ (or $\dot{V}O_{2peak}$) between 43 and 57 mL·kg$^{-1}$·min$^{-1}$. Based on the 95 % LoA we cannot claim that any of these 523 soldiers would differ in directly measured $\dot{V}O_{2max}$ from another. Consequently, estimated $\dot{V}O_{2max}$ from the 20 m SRT may be interpreted as a rather vague indication of directly measured $\dot{V}O_{2max}$ in individuals. It should be mentioned that some criticize the 95 % LoA for being too stringent and conservative for practical use.[54] Thus, to conclude that the 20 m SRT is not a valid test based on the "worst case" 1.96 SD limits may be somewhat unfair.

Another aspect of validity is the mean difference (bias) between estimated and directly measured $\dot{V}O_{2max}$. Paper I demonstrated that the bias varied among the different 20 m SRT equations that we cross-validated on cadets. Our new HG-generated equation showed no significant bias against directly measured $\dot{V}O_{2max}$. Moreover, no biases were evident for the two equations produced by Léger et al.[78, 84] The much cited and used Ramsbottom equation underestimated $\dot{V}O_{2max}$ by almost 6 mL·kg$^{-1}$·min$^{-1}$. Thus, if it is important to estimate $\dot{V}O_{2max}$ with the smallest possible bias against directly measured $\dot{V}O_{2max}$, selecting the correct 20 m SRT prediction equation is crucial. Paper I also illustrates the difficulty of comparing $\dot{V}O_{2max}$ data among studies that use different prediction equations. Results may differ simply because different equations were employed. For instance, mean estimated $\dot{V}O_{2max}$ in our cadets was 16 % higher with the Stickland et al. equation compared to the Ramsbottom et al. equation. For the HG soldiers tested in paper I, the corresponding difference would be 23 %. We did not find a significant mean difference between estimated and directly measured $\dot{V}O_{2max}$ when we cross-validated our new equation on cadets. This indicates that our new equation may be generalized to soldiers with other physical characteristics (age, fitness levels, etc.) than HG soldiers.

Directly measured $\dot{V}O_{2max}$ was used as the reference measurement in our 20 m SRT method comparison study. While $\dot{V}O_{2max}$ is indeed the true gold standard for aerobic capacity, it may not be the best predictor for the ability to carry out prolonged physically demanding military work. Indeed, performance in the 20 m SRT depends highly on $\dot{V}O_{2max}$. Yet, it also depends on other physiological and psychological factors that could be important for performance in prolonged military work. When selecting soldiers for prolonged military work, a performance test like the 20 m SRT might therefore be equally valid compared to direct measurements of $\dot{V}O_{2max}$. Thus, the 20 m SRT may still be a good predictor of the ability to carry out prolonged hard military work, despite the rather wide LoA against directly measured $\dot{V}O_{2max}$. However, if accurate measurements of the important physiological factor $\dot{V}O_{2max}$ are needed, it should be acknowledged that the 20 m SRT has limitations. In such cases, direct measurements should be carried out instead.

A related question is whether our reference measure $\dot{V}O_{2max}$ should have been expressed in $mL \cdot min^{-1}$, $mL \cdot kg^{-1} \cdot min^{-1}$, $mL \cdot kg^{-0.67} \cdot min^{-1}$, or with any other scaling factor. Expressing $\dot{V}O_{2max}$ as $mL \cdot kg^{-1} \cdot min^{-1}$ (i.e. accounting only for the person's own body weight) is not optimal for soldiers who typically work with external load on the body.[33, 74] As more external weight is carried, $\dot{V}O_{2max}$ expressed in more absolute terms will correlate better with performance in the actual work.[252] Thus, when we used $\dot{V}O_{2max}$ in $mL \cdot kg^{-1} \cdot min^{-1}$ as our reference measure, this is primarily theoretically sound for unloaded conditions.

### 4.1.2 Reliability and validity of field methods to predict body fat (Paper II)

Reliability and validity of the studied body composition field methods varied according to gender, which equation was used, and whether the focus was on reliability or validity. The results often differed more within each method (comparing different equations), than between the different field methods. Still, for both men and women, the SF-BIA method generally showed slightly better test–retest LoA and CV than the other field methods. A test–retest 95 % LoA of ± 1 % BF was within range, if the most reliable SF-BIA equations were used. The MF-BIA method as well as the combined SKF and SF-BIA method also demonstrated good reliability, with ICC values ≥ 0.97 for both men and women. The SKF method alone was somewhat less reliable. A significantly higher percent BF at retest was observed for the five male SKF equations, since six out of seven SKF sites were significantly higher at retest. This bias is most likely due to a systematic error made by the investigator team, and demonstrates that SKF measurements can be difficult to obtain accurately. In a previous review of body composition field studies, it was concluded that BIA has better reproducibility than SKF.[253]

Wagner and Hayward[254] also highlighted that BIA can be a reliable field method, and that the SKF method requires a considerable amount of technical skill. However, others demonstrated similar or higher reliability in SKF compared to BIA.[255-257] Inter-study variations in SKF measurement skills and study participants' age, body composition and gender may lead to different conclusions regarding reliability.[258] Yet, it seems reasonable to conclude that BIA is usually a reliable field method, and that SKF may also be a reliable method if sufficient training and practice is given. Hence, both methods have the potential to be sufficiently reliable for traditional evaluations in the military.

It is difficult to conclude which field method was the most valid in our study. In terms of Pearson correlation, the *r* ranged from 0.76 to 0.93 among all methods and equations. The MF-BIA and the combined SKF and SF-BIA equation demonstrated the highest *r* against DXA in both men and women. In terms of the 95 % LoA, some of the SKF equations in men, and some of the SF-BIA equations in women produced the narrowest LoA (about ± 4 BF percentage points). Using these methods, a soldier estimated at 20 % BF should have a true value between 16 and 24 %. In terms of bias (mean difference), our data showed that many of the equations produced significantly higher or lower mean percent BF when compared to DXA. Such mean differences may also hamper comparisons of body composition values among studies that use different methods or equations. In Paper III, we reported that REG-HG soldiers had a mean BF at 20.0 %, using the Sun et al. equation. However, if we had chosen to use the Deurenberg et al. equation, mean BF in REG-HG soldiers would have been estimated at 24.8 %, while the Segal et al. fatness specific equation would have produced a mean BF of 16.6 %. This example illustrates the most extreme situation, since comparing some of the other equations would have given smaller mean differences. Still, similar to the 20 m SRT equations, this example illustrates the problem that may arise when comparing mean predicted percent BF among studies using different methods and equations.

Many previous studies have investigated validity of body composition field methods, particularly SKF and SF-BIA.[109, 254, 259-262] During the last decade, several studies on validity of the MF-BIA method were also published,[263-265] while methods combining SKF and SF-BIA are less commonly investigated. Conclusions related to validity in these field methods may vary greatly among different studies.[119] Reasons for the conflicting results mirror different reference methods, populations (age, gender, ethnicity, and anthropometrics), field devices (calipers and BIA devices), analytical goals and statistical methods.

Validation studies carried out on military personnel may also present conflicting conclusions and different recommendations. Some of these studies are difficult to interpret, since they compared two or more field methods without including comparison to an acknowledged reference method.[266-268]

Several method comparison studies in military populations were carried out in the USA in the 1970–80s, primarily investigating SKF and circumference based equations.[269-271] Hodgdon[271] reviewed earlier validation studies of circumference based BF equations used in the US Defence Forces, and concluded that they were equally valid to SKF equations. Pearson correlation of the circumference based equations were $r$ = 0.73–0.90 and standard error of estimate ranged from 3.5 to 4.1 % BF compared to underwater weighing. Later, Kremer et al.[272] compared percent BF from SF-BIA, a circumference method and underwater weighing (the reference method) in US Air Force men and women. They found slightly higher $r$ and lower standard error of estimate for the circumference method, compared to the BIA method. Another study comparing circumference based equations against DXA in 496 male soldiers also concluded that a combined waist and neck circumference measure gives a good estimate of percent BF.[273] Finally, Lintsi et al.[274] validated BF estimations from SKF, SF-BIA and BMI equations against DXA in young Estonian conscripts. They found slightly higher correlation and narrower 95 % LoA for the SKF equation, compared to the other two field methods. In a review of body composition measurements in soldiers, Friedl[118] stated that circumference measurements are both valid and practical, and that abdominal circumferences is "...superior to sophisticated state-of-the art scientific methods of body fat assessment in regards to the outcomes of military interest". He stated that very accurate total BF measurement is less important than measurement of intraabdominal fat, which he claimed is best evaluated in the military by abdominal circumference. Yet, others raised concerns about the validity of circumference based equations and suggest caution when using these measurements for individual military career decisions.[275] Moreover, low sensitivity of detecting changes in percent BF was demonstrated for both SKF and circumference based equations in US Army women after 8 weeks of basic combat training.[276]

In a review of body composition measurement methods, Norgan[253] concluded that it is difficult to choose among different test methods. Instead of concluding which field method is the most valid, Norgan emphasized that it is necessary to use population specific prediction equations for all field methods. This is in accordance with our findings which showed that validity and reliability often varied more between different equations for the same field method, compared to among the methods themselves.

When discussing validity, it should be acknowledged that a true gold standard or perfect reference method for *in vivo* body composition assessment does not exist.[219] When comparing percent BF measurements obtained from DXA versus other reference methods, rather large measurement errors are reported.[219, 277] Moreover, different DXA machines and different software versions may produce different mean body composition values.[109, 278, 279] Hence, we have to account for the possibility that some of the measurement error between our field methods and DXA scans may in fact be due to error in the reference method.

### 4.1.3 Physical fitness in Home Guard soldiers (Paper III)

Paper III presented reference data on anthropometrics, body composition and aerobic fitness in Norwegian HG soldiers. Ideally, these data should have been accompanied by a thorough task and demand analysis of the work typical for HG soldiers. Such an analysis would have made it easier to interpret the fitness data, and to conclude whether HG soldiers have the necessary physical capacity. Although Paper IV revealed data on physical activity levels during HG training, this is not sufficient evidence for generating valid minimum requirements for fitness in HG soldiers. However, it could be argued that HG soldiers fight on the same battleground as full-time soldiers, and that general fitness recommendations for “ordinary” soldiers should apply also to HG soldiers. As mentioned in the introduction, a $\dot{V}O_{2max}$ of at least 43–50 $mL \cdot kg^{-1} \cdot min^{-1}$ has previously been recommended by NATO.[25] In a more recent study, Pihlainen et al.[45] recommend a $\dot{V}O_{2max}$ of minimum 45–50 $mL \cdot kg^{-1} \cdot min^{-1}$ to carry out loaded marching, artillery field preparation and digging. However, such recommendations should be treated with caution, since intensity of the work may be arbitrarily set, or based on self-paced work – which means that the intensity is limited by the fitness levels of the subjects tested. Still, if we accept 43 $mL \cdot kg^{-1} \cdot min^{-1}$ as a minimum requirement for soldiers, only 13 % of the REG-HG soldiers and 8 % of the RAP-HG soldiers were below this limit (Figure 8).

Concerning body composition, the US Army’s upper limits of percent BF could be used as a guideline. These limits vary according to age; from 20 to 26 % for male soldiers.[118] Twenty-five % of the REG-HG soldiers and 12 % of the RAP-HG soldiers exceeded these BF limits. Moreover, between 9 and 20 % of the HG soldiers exceeded civilian health guidelines for BMI (> 30 $kg \cdot m^{-2}$) and WC limits (> 102 cm), which are associated with obesity.[280] Among the 685 HG soldiers who were tested on both aerobic fitness, BF, BMI and WC, 219 (32 %) did not fulfill the recommendations in one or more of the variables. Hence, one out of three HG soldiers has either too low aerobic fitness, or is overweight or obese, according to military and civilian recommendations.

Table 3 in the introduction presents a selection of previous studies on $\dot{V}O_{2max}$ and percent BF in soldiers worldwide. Based on this table, Norwegian HG soldiers are well within the range of previous $\dot{V}O_{2max}$ figures reported on military personnel. Our HG soldiers had a 10–15 % lower $\dot{V}O_{2peak}$ compared to the highest values reported. Home Guard soldiers are typically older, have lower volumes of military training and are selected with lower emphasis on fitness, compared to soldiers in many professional forces. Hence, it is natural that they produce lower $\dot{V}O_{2peak}$ values compared to younger full-time soldiers. Compared to previous data on reserve soldiers, HG soldiers appear to have very similar mean $\dot{V}O_{2peak}$ to US male National Guard soldiers,[139] but remarkably higher values compared to Finnish reservists.[145, 146] The discrepancy between reported aerobic capacity in Norwegian and Finnish reserve soldiers is probably partly due to methodological differences. Two previous studies on UK Army reserves reported $\dot{V}O_{2max}$ values of 39–47 mL·kg$^{-1}$·min$^{-1}$ estimated from the 20 m SRT.[128, 165] The papers do not explain whether the soldiers (n = 20–21) were representative samples of UK reservists. However, the Ramsbottom et al. prediction equation was used, which clearly underestimates $\dot{V}O_{2max}$ according to Paper I. In fact, running performance was slightly better in one of the UK reserve samples studied,[128] compared to our REG-HG soldiers.

Norwegian HG soldiers had a somewhat higher percent BF compared to most soldiers presented in Table 3. Concentrating on reserve soldiers, our HG soldiers had somewhat higher mean BMI, WC and percent BF compared with Finnish reservists,[145, 146] and similar or higher mean percent BF compared to UK Army reserves.[128, 165] On the other hand, our HG soldiers had lower BF and also lower BMI compared to US Arizona National Guard soldiers.[139] As demonstrated in Paper II, different prediction equations and methods may yield significantly different mean percent BF values, which likely hamper direct comparisons between studies. In Paper III, BF was estimated with the Sun et al. equation,[240] which Paper II showed overestimated BF by 1.1 percentage points against DXA. Hence, our presented mean % BF values in HG soldiers might be slightly overestimated. The reason why we used the Sun et al. equation in Paper III, and not one of the other equations that demonstrated smaller bias against DXA (Paper II), was that the Sun et al. equation was developed based on a large validation study, partly including military personnel. Moreover, the equation that was most valid in male cadets is not necessarily the most valid in male HG soldiers. Ideally, we should have validated the BF prediction equations also on HG soldiers, and not only on cadets.

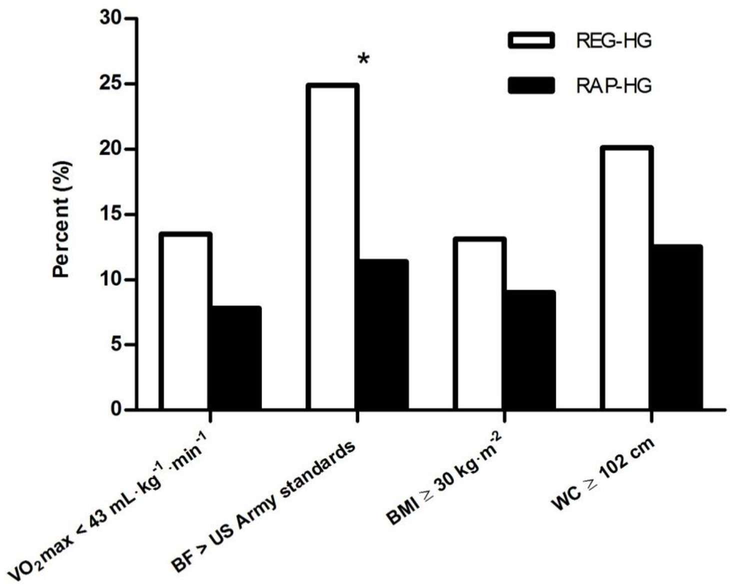


**Figure 8.** The percentage of REG-HG and RAP-HG soldiers who did not meet recommended levels for maximal oxygen uptake ($\dot{V}O_{2max}$), body fat (BF), body mass index (BMI) and waist circumference (WC).
*Significantly different between REG-HG and RAP-HG ($P < 0.05$).

### 4.1.4 Physical activity in Home Guard soldiers (Paper IV)

Paper IV presented reference data on objectively measured physical activity in REG-HG soldiers during HG training and civilian life. The presented data can be used for comparison against previous studies on physical activity in military and civilian populations. Yet, few studies have been published on objectively measured physical activity levels in soldiers, in particular reserve soldiers (see Table 4). Except for data on steps per day in a non-representative sample of US National Guard soldiers,[195] no other studies on objectively measured physical activity in reserve soldiers were identified. More data are available for regular full-time soldiers, but they are often collected during physically strenuous field exercises, where the physical demands are typically elevated compared to normal days.[42] In the review by Tharion et al.,[42] the mean (SD) TEE was 4610 (650) kcal, which is clearly higher than what we found among HG soldiers. However, if we refer to Table 4, the HG soldiers' physical activity levels were within the range of what is previously demonstrated in large scale studies of international soldiers and military personnel.

We may also compare HG soldiers' physical activity levels against several previous large scale studies on civilian adults.[281] Hansen et al.[282] examined a large sample of Norwegian adult men using the ActiGraph accelerometer. They demonstrated both fewer steps per day and remarkably fewer minutes of ≥ moderate intensity (3 METs) per day, compared to our HG soldiers' civilian physical activity levels (8188 vs. 9590 steps and 37 vs. 179 minutes, respectively). One reason for the discrepancy between the two studies could be that Hansen et al. included men between 20 and 64 years of age, while our HG soldiers were between 21 and 44 years old. More important, Hansen et al. used a different type of physical activity monitor and different data processing methods (software algorithms, cut-off points, etc.) than in the present study. Similar to the difficulties of comparing physical fitness data among studies, comparisons of physical activity levels among studies are often hampered by methodological differences.[14, 283]

Since HG soldiers only attend HG training a few days per year (or less than every year), it is the exercise carried out during civilian life that makes a difference towards developing HG soldiers' fitness levels. The present study showed that the majority of the exercise carried out during civilian life was of low intensity (3–6 METs). Only four minutes per day (less than half an hour per week) could be classified as very vigorous physical activity (> 9 METs). Apparently, this exercise level is still sufficient to produce a relatively good aerobic fitness level. The physical activity data indicate that there is potential for an increase in aerobic fitness in HG soldiers if the soldiers carry out more high intensity exercise, which is usually considered to be the most effective training.[284, 285]

While it is typically claimed that the physical demands on soldiers are high, the present study adds a nuance to this perception, as physical activity levels of HG soldiers were not elevated during HG training compared to civilian life. Actually, significantly less very vigorous physical activity was performed during HG training compared to civilian life. One reason for the lack of high intensity physical activity during HG training may come from the fact that REG-HG soldiers are not volunteers, and commanders might thereby be reluctant to implement physically strenuous training sessions on soldiers not accustomed (or eager) to such training. Moreover, it is claimed that the HG training days too frequently include long periods of waiting for orders,[286] which leads to a large volume of low intensity activity and rest. Yet, it must be emphasized that the physical demands during HG training do not necessarily reflect the physical demands in real scenario HG operations.

## 4.2 Methodological considerations

### 4.2.1 Study design

Research can be divided into observational or experimental studies.[216] In medical research, experimental studies (and in particular the randomized control trial) are typically considered to produce stronger evidence than observational studies.[287, 288] Yet, the aim of the present study was not to study the effect of an intervention, but rather observe how different methods compare, and report on descriptive cross-sectional data. Hence, the observational design in our study should be appropriate to answer the given research questions.

This thesis is based on data from three separate studies. It was first after the studies had been designed and the data collection had commenced, that the idea of merging these studies into a PhD project was established. This has led to some methodological challenges. For instance, the method comparison study on body composition did not include HG soldiers. Since it is stressed in the literature that body composition equations are population specific,[119] we cannot fully trust that the most valid and reliable SF-BIA equation in male cadets (Paper II) would also be the best option when applied to male HG soldiers in Paper III. Moreover, a method comparison study related to the physical activity monitor is not included in this thesis. Ideally, all main measurement tools used to describe physical fitness and physical activity in HG soldiers should have been checked for validity and reliability in representative subsamples of HG soldiers.

Another discussion point is that the physical fitness tests in the Moving Home Guard Soldiers Study took place during military training days. Thus, the fitness tests were performed under field conditions, with less standardization regarding previous exercise, nutrition, sleep, climatic conditions, test facilities etc., compared to a more uniformed and optimized laboratory setting. This may have influenced negatively on internal validity and the soldiers' ability to perform at their best.

It should also be noted that the physical activity monitoring during civilian life occurred in the week following the HG military training days. It is possible that the HG training influenced the level of physical activity on the successive week and that a carryover effect altered the activity level during the civilian life measurement period. Preferably, the civilian measurements should have been completed on any random civilian week, but this was not feasible.

Altman suggested that method comparison studies should include at least 50 subjects.[216] The total number of subjects in the 20 m SRT method comparison study (n = 66) and the body composition method comparison study (n = 65) both exceed Altman's recommendation. Yet, since we split the analysis according to sub-groups (HG soldiers vs. cadets, men vs. women), our sample sizes became somewhat small. This increases the uncertainty of our LoA estimates.[216]

A total of 799 HG soldiers volunteered to participate in the Moving Home Guard Soldiers Study. This is a relatively large sample size compared to previous studies in this area (see Table 3 and 4). The aim of the sampling procedure was to secure a geographically and force-representative sample. Overall, this goal was probably achieved; despite some challenges related to aspects of the randomization process (see Paper III). In retrospect, we should have included more (over-sampled) RAP-HG soldiers, since we later decided to split the analysis on HG force. Only 89 RAP-HG soldiers from two districts and four troops were recruited, and this increases the uncertainty of the RAP-HG fitness data. In addition, physical activity levels of RAP-HG soldiers were not reported since few wore the monitor during HG training.

The compliance rate in all three studies was generally high. For instance, 88 % of the invited HG soldiers volunteered (Paper III). Still, some soldiers later refrained from undergoing all tests, some were unavailable when the tests were administered and some data were lost for other reasons. The number of drop-outs is particularly high for the study investigating physical activity levels (Paper IV). Although we conducted missing data analysis which indicates that data seem to be missing at random, it is still a weakness that we lost a substantial amount of data, particularly related to the physical activity monitoring. Another weakness is that we do not have exact figures for the percentage of HG soldiers who actually met for the HG training. According to the district officers, between 50 and 95 % (median 70 %) of the HG soldiers met for the HG training. The district officers stated that the “no-show” soldiers were probably missing at random, but we have no data available to verify this.

Regarding statistical analysis, Papers I and II include analyses of Pearson *r*, ICC and 95 % LoA. In addition, analyses of CV are included in this thesis. There is a general consensus that correlation coefficients should not be presented alone, since they are influenced by the variance (heterogeneity) of the sample and may be difficult to interpret.[216] However, there is debate as to how absolute reliability and validity are best expressed in method comparison studies related to sport and exercise. Some argue that 95 % LoA (including Bland-Altman plots) should be the method of choice,[289] while others prefer the typical error or standard error of estimate.[54] Our choice to use LoA is a personal preference, which is at the same time supported by its widespread use in method comparison studies.

In the Moving Home Guard Soldiers Study (Papers III and IV), we recruited HG soldiers based on troop-level (i.e. not on individual level). This may introduce some inherent correlation between the subjects within each cluster (troop). Since we have many clusters (38 troops), this may not be problematic,[216] but we still adjusted for the cluster-randomized design by using the linear mixed-model. This adjustment reduces the risk of making type I errors, but also increases the risk of making type II errors.

### 4.2.2 Measurements

A maximal incremental treadmill protocol along with direct measurement of $\dot{V}O_{2max}$ was used as the reference measurement in Paper I. Although this treadmill protocol has been used for many years by the Norwegian School of Sport Sciences, it has apparently not yet been evaluated for validity and reliability. Based on a previous review of various direct $\dot{V}O_{2max}$ protocols,[290] we may still assume that our protocol produces valid $\dot{V}O_{2max}$ figures. The type of $\dot{V}O_2$ analyzer utilized should also produce accurate measurements, according to previous validation studies.[291-293] Yet, it is demonstrated that online metabolic analyzers might vary considerably when compared to other analyzers and the Douglas bag method, even when correct calibration procedures are followed.[294]

In Paper II, we used DXA as our reference measure for BF. As previously stated, a universally accepted gold standard method for body composition measurement does not exist, and different machines and software may produce different body composition values. Still, the DXA method is much used in validation studies and has merit as a reasonably precise whole-body method.[109] Studies of validity and reliability of the exact model and software we used in our study are not identified.

In Paper III, aerobic capacity was measured in HG soldiers with the 20 m SRT. While aerobic capacity is best measured with a direct procedure, this was not feasible in the present study. Yet, our method comparison study showed relatively good agreement between the 20 m SRT and directly measured $\dot{V}O_{2max}$, particularly at the group level. This methodological agreement is generally also confirmed in previous research.[78, 248] Furthermore, the 20 m SRT is a maximal test and such tests are shown to correlate better with directly measured $\dot{V}O_{2max}$ compared to submaximal tests.[46, 82, 295] Therefore, we believe the 20 m SRT provided us with valid estimations of aerobic capacity in HG soldiers at the group level. The included HR measurements helped us to interpret whether the soldiers ran until maximal effort, which is a prerequisite for valid estimations of aerobic fitness levels from the 20 m SRT test.

In Paper III, we also used an indirect method to estimate percent BF and skeletal muscle mass in HG soldiers. Based on our own method comparison study and the literature reviewed, we believe a suitable prediction equation was selected to estimate BF. However, we did not use HG soldiers as test subjects in the method comparison study, which leads to some uncertainty about the accuracy of our presented BF values in Paper III. Moreover, we did not validate the skeletal muscle mass estimation equation utilized. We still believe this equation was applicable to our HG soldiers, since it was developed in a large sample of healthy adult Caucasians.[244]

In Paper IV, physical activity was measured objectively with the SenseWear Armband monitor. Such an objective method is generally considered more valid than self-reported questionnaires.[176] Although the SenseWear Armband monitor is not considered a criterion method, validity of this monitor is generally reported to be good or acceptable.[14, 172, 223] We previously validated the SenseWear Armband in civilian and military personnel, and concluded that it estimated minutes in moderate-to-vigorous physical activity with narrower LoA than the frequently used ActiGraph accelerometer.[179] Yet, we were not able to validate the monitor specifically on HG soldiers. Previous studies are scarce on the SenseWear Armband monitors' validity under loaded conditions, but it has been demonstrated that the monitor underestimates TEE and METs during external weight lifting.[296] Since HG training typically includes some external weight carriage, this may have led to under-estimated physical activity figures during HG training.

It is a limitation of the present study that no strength tests were included in the study on physical fitness in HG soldiers. Although we measured FFM and skeletal muscle mass, which is essential for developing force and correlated with muscular strength,[297] separate strength performance tests would have contributed significantly to the description of the fitness levels of HG soldiers. The strength tests were omitted due to practical reasons and resource limitations.

## 4.3 Implications, recommendations and future research perspectives

### 4.3.1 Aerobic fitness testing in soldiers

Aerobic fitness is one of the key physical fitness parameters in soldiers, and a test battery developed for military personnel should include this component. Unloaded distance runs (e.g. the 1.5 mile run, 3000 meter run, etc.) are probably the most frequently used aerobic fitness tests in soldiers today. Reported reliability and validity of such distance runs in soldiers or healthy civilians vary among different studies, but are generally comparable to our results for the 20 m SRT.[68-72, 249, 298, 299] Thus, the 20 m SRT should be considered equally scientifically sound as traditional distance runs. Advantages of the 20 m SRT are that it can be carried out indoors, running pace is dictated (eliminates the chance of sub-optimal pacing) and it is probably perceived as less physically demanding compared to a timed run. Home Guard soldiers previously rated the 20 m SRT as more likeable than the 3000 meter run,[213] which may lead to increased adherence and positive attitude towards testing. Disadvantages of the 20 m SRT are that it requires some equipment and that fewer subjects can be tested at the same time, compared to a traditional timed run. As for any unloaded running test, it could be argued that the 20 m SRT favors lighter personnel, and that an external weight carriage test would be more valid as a predictor of aerobic related military work capacity.[74]

The 20 m SRT exists in several protocol variants,[300] and it is claimed that at least seventeen $\dot{V}O_{2max}$ prediction equations have been developed.[301] The current study showed that different equations may estimate $\dot{V}O_{2max}$ with large divergence. For intra-study comparisons of fitness levels, it is therefore important to report which protocol and equation is used. Performance raw scores should be reported, for example as total number of shuttles, LHL or end speed; not only as estimated $\dot{V}O_{2max}$. One habituation trial seems beneficial to increase reliability.

Paper I gives valuable information to military researchers and practitioners about the expected measurement errors of the 20 m SRT, and helps with interpretation of test results in soldiers. Future studies in this area may include a method comparison study including military women, as no women were included in the present study. The test's ability to detect changes in aerobic capacity (responsiveness) is also not yet well established. More broadly, it may be beneficial to further investigate whether $\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$) should indeed be treated as the gold standard measurement for aerobic-related military physical work. The ability of unloaded running tests to estimate performance in lower intensity loaded military work may also be further scrutinized.

### 4.3.2 Body composition testing in soldiers

The present study did not identify one specific body composition field method which clearly stood out as the most valid and reliable method for use in military personnel. However, careful selection of an appropriate prediction equation seems important, irrespective of which method is used. Skinfold measurements should only be used if the test leader is properly trained and experienced, which could restrict its practical use in the military. The MF-BIA did not show improved validity and reliability over the SF-BIA, and the higher cost may not justify its use if the only outcome measure is percent BF. The SF-BIA is easy to administer, low-cost and a quick method applicable for the military, and demonstrated overall good reliability and validity (especially for women). However, standardization of external factors seems necessary for BIA. The combined SKF and SF-BIA equation demonstrated good validity in men, but is less practical and requires more time than the SF-BIA. We did not include circumference measurements in our study, but this method is previously recommended for evaluation of soldiers' body composition, as it is easy to learn and quick to carry out.[271]

Body composition can be a socially sensitive measure for some soldiers. Military practitioners should therefore consider whether body composition measurements are relevant and needed, and care should be taken related to individual feedback procedures.

Our study demonstrated rather large LoA between the investigated field methods and DXA. It is clear from previous research that SKF and BIA are more valid methods than BMI in predicting body composition.[119] In our study, the Pearson correlation between BMI and DXA measured percent BF was $r = 0.61$ ($P < 0.001$) for men and $r = 0.70$ ($P < 0.001$) for women (data not shown). This is clearly lower than what we found for SKF and BIA against DXA. Thus, if body composition measurements are required at soldiers' individual levels, the military should consider excluding BMI measurements, or possibly complementing them with a more valid body composition test.

Body composition is often referred to as a component of physical fitness because of its interaction with other fitness factors.[13] Yet, if a soldier is able to run fast for long and short distances during loaded and unloaded conditions, and performs well in lifting his own body weight and external weight, it may be questioned whether body composition adds to the interpretation of the soldiers' physical performance levels. Thus, an area of further research may be to investigate the role body composition plays in military work capacity, after controlling for muscle strength and aerobic capacity. Other possible research areas are whether BF or muscle mass is the most relevant measurement in soldiers, and further clarification of which types of military tasks are related to the different body composition variables.

### 4.3.3 Are Home Guard soldiers "fit to fight"?

One reason for initiating the present study was to provide the Inspector General of the HG with facts related to physical fitness and physical activity levels in HG soldiers, so that a more informed decision could be made of whether HG soldiers need to increase their physical fitness. Paper IV revealed that physical activity during HG military training was not higher than during civilian life. Actually, more high intensity activity was carried out in civilian life compared to HG military training. A key task of the REG-HG soldiers is to protect objects (buildings, roads, etc.), which typically consists of stationary work. The low volume of high intensity physical activity during HG training is therefore not unexpected. Thus, with a mean $\dot{V}O_{2peak}$ of about 50 $mL \cdot kg^{-1} \cdot min^{-1}$, the majority of the HG soldiers seem to have sufficient aerobic fitness to carry out the pre-planned HG-tasks. Moreover, the majority of the HG soldiers fulfilled the minimum requirement previously identified by NATO (a $\dot{V}O_{2max} \geq 43$ $mL \cdot kg^{-1} \cdot min^{-1}$). Accordingly, it is tempting to conclude that HG soldiers are in fact "fit to fight", and that immediate action geared towards increasing physical fitness and physical activity in HG soldiers does not seem warranted.

Despite the abovementioned, it is still possible to argue for increased awareness related to physical fitness and physical activity in HG soldiers. One third of the soldiers did not fulfill the recommendations in one or more of the fitness variables, and 56 % did not achieve the recommended 10,000 steps/day. Moreover, in real-scenario civilian and military crises, the HG soldiers may have to carry out unforeseen tasks with higher physical demands than experienced during HG training. Increased physical capacity would also mean higher buffer against fatigue, and increased flexibility in the type of jobs that can be carried out successfully. Improved fitness level may also increase the status of the HG force, and lead to higher recognition among peer professional soldiers and the civilian society. Furthermore, the legitimacy of the aerobic fitness recommendations set by NATO could be questioned, since these values were developed in the 1980s, and job tasks and demands may have changed since then. It should also be acknowledged that the present study does not include a thorough task and demand analysis of the physical demands placed on HG soldiers. Our physical activity monitoring primarily reflected aerobic related demands, leaving the strength demands uninvestigated. Hence, the physical demands of the HG service may in fact be more multifaceted and higher than they appear from the present study. Thus, it is difficult to draw clear conclusions on whether HG soldiers are indeed "fit to fight". Further analysis of the physical tasks and demands of HG service may help to answer this question. Yet, uncertainty of the actual demands will probably always remain, since military operations typically include unforeseen scenarios. Accordingly, in the future, it might be more beneficial for the HG to focus on optimization of fitness.

If the HG decides to take action towards increasing physical fitness and physical activity in their soldiers, some recommendations may be given. First, it should be acknowledged that this task is likely more difficult than if applied to conscripts, officers or professional soldiers who are permanently located at the same place, and are under daily military command. Implementing exercise training during the few HG military training days will not deliver significant gains, so HG soldiers must be targeted in their civilian life. In our previous HG pilot study, we investigated what kind of civilian life intervention could be effective over a five month period.[213] Neither free access to a local gym, nor access to an exercise program including free gym clothes and running shoes increased physical fitness or physical activity levels, compared to the non-treated control group. An alternative idea is to organize small local exercise training groups. Important side-effects of such an initiative could be increased visibility, coherence and unity, and a positive promotion of the HG in the local community. Nevertheless, if the HG training week only includes physically light work, it is more difficult to motivate HG soldiers to exercise and stay fit for operational reasons. Including some more physically challenging job tasks during the REG-HG training week may stimulate REG-HG soldiers to exercise more during their civilian life.

This descriptive study on physical fitness and physical activity in HG soldiers raises both new questions and possible future studies. A more comprehensive physical task and demand analysis of the HG service would be beneficial. The present study did not cover this aspect sufficiently, which makes it difficult to conclude on whether HG soldiers are “fit to fight”. More broadly, the previous general NATO recommendations on aerobic capacity may well be revised, and supplemented with minimum requirements for muscle strength. Such recommendations could be used as a starting point when interpreting fitness levels of various types of military forces. If increased awareness of physical fitness and physical activity is desired in the HG, the previously mentioned HG pilot intervention study may be carried out with an improved design. Another worthwhile study could be to investigate secular changes of fitness in HG soldiers, especially since several important changes have occurred in the Norwegian military system lately. Compulsory conscription for both men and women was established in 2015, and it is therefore expected that more women will serve in the future HG. The present study only included men, since few women were enrolled in the HG at the time of the study. Inclusion of more women will most likely change the physical fitness profile of the future HG. Moreover, conscript service is now more exclusive as fewer soldiers are needed for service. This will likely increase the minimum physical requirements for conscript service, which again may alter the fitness profile of future HG soldiers. A future study on physical fitness in HG soldiers should include a more representative sample of both REG-HG and RAP-HG soldiers, and men and women.

# 5 CONCLUSIONS

The following conclusions can be drawn from the research aims presented in chapter 1.6:

**Reliability and validity of the 20 m SRT**

- This thesis established reliability and validity statistics for the 20 m SRT in military personnel. A new $\dot{V}O_{2max}$ prediction equation was developed and later cross-validated in a separate sample.
- The 20 m SRT seems to be sufficiently reliable for screening aerobic fitness in military personnel.
- Validity of the 20 m SRT seems relatively similar to what is previously demonstrated in traditional distance running tests (e.g. the 1.5 mile run). While $\dot{V}O_{2max}$ may be estimated accurately on a group level, a relatively large measurement error should be accounted for at the individual level.
- Several published equations exist for predicting $\dot{V}O_{2max}$ from the 20 m SRT. We found up to 23 % discrepancy for mean estimated $\dot{V}O_{2max}$ among different equations. Thus, care should be taken when selecting an equation to predict $\dot{V}O_{2max}$.

**Reliability and validity of SKF and BIA to predict body fat**

- This thesis established reliability and validity statistics for SKF and BIA methods in predicting percent BF in male and female military personnel.
- Reliability and validity varied substantially among the equations examined. The best methods and equations produced test–retest 95 % LoA below ± 1 BF percentage points, whereas the corresponding validity figures were ± 3.5 BF percentage points.
- None of the field methods stood out as clearly superior to the others in terms of both reliability and validity. Both SKF and BIA are potentially reliable field methods, while a relatively large measurement error should be accounted for at the individual level when predicting percent BF.
- There may be large discrepancies in mean estimated percent BF between different equations applied on the same raw data. Thus, care should be taken when selecting an equation to predict BF.

**Physical fitness of Home Guard soldiers**

- Mean 20 m SRT performance in Norwegian HG soldiers was 70 shuttles, which corresponds to a $\dot{V}O_{2peak}$ of approximately 50 $mL \cdot kg^{-1} \cdot min^{-1}$ when using our population specific prediction equation presented in Paper I. Mean BMI, WC and BF were 26.1 $kg \cdot m^{-2}$, 94.0 cm and 19.7 %, respectively.
- Differences in anthropometrics and aerobic fitness related to type of HG force or military rank were generally small or nonexistent.

**Physical activity of Home Guard soldiers**

- The median time spent in ≥ moderate intensity physical activity during civilian life was approximately 3 hours per day. This included 4 minutes per day with very vigorous physical activity (> 9 METs). The commonly recommended 10,000 steps per day was reached by 44 % of the soldiers during civilian life.
- The HG soldiers spent significantly more time in moderate intensity physical activity during HG training compared to civilian life, but less time in vigorous and very vigorous physical activity.

**Are Home Guard soldiers "fit to fight"?**

- Approximately one out of three HG soldiers had either too low aerobic fitness, or was overweight or obese, according to military and civilian recommendations.
- The low volumes of high intensity physical activity during HG training may indicate that the aerobic job demands in HG military service are relatively low.
- The majority of the HG soldiers appear to have a sufficient physical fitness level to carry out the pre-planned jobs designated for HG soldiers. Yet, increased physical fitness and physical activity may still be valuable to better prepare HG soldiers for possible unforeseen tasks with higher physical demands.

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# PAPER I

**MILITARY MEDICINE,** 176, 5:513, 2011

# Validity and Reliability of the 20 Meter Shuttle Run Test in Military Personnel

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**ABSTRACT** Aerobic fitness is regularly monitored in military personnel, as occupational demands require a certain level of fitness. Distance run (eg, 2 mile) is typically carried out to measure aerobic fitness, but an alternative test could be the 20 meter shuttle run test (20 m SRT). The present study aimed to evaluate validity and reliability of this test in military personnel. An equation for predicting maximal oxygen uptake ($VO_{2max}$) was developed on 38 Home Guard soldiers and cross validated in 28 Air Force cadets. Reliability of the 20 m SRT, expressed as mean difference in estimated $VO_{2max}$ ± 95% limits of agreement, was −0.8 ± 3.1 mL·kg$^{-1}$·min$^{-1}$. Mean difference ± limits of agreement between estimated and measured $VO_{2max}$ was −0.4 ± 6.2 mL·kg$^{-1}$·min$^{-1}$. The 20 m SRT seems to be a reliable test, although validity is less certain, as relatively high variability was observed between measured and estimated $VO_{2max}$ from the 20 m SRT.

## INTRODUCTION

Adequate level of physical fitness is considered to be one of the basic features of military personnel because of the possible high physical occupational demands. Thus, muscular strength and aerobic fitness are frequently evaluated in military personnel. Direct measurement of maximal oxygen uptake ($VO_{2max}$) is often considered the "gold standard" method for determination of aerobic fitness.[1] However, such a method is usually not applied to routine testing of soldiers, as it is time consuming and expensive. Hence, field tests like the 2-mile run, the 12-minutes run, or the 3,000-m run are widely used among nations to monitor aerobic fitness in military personnel.[2–5] These outdoor running tests are easy to administer and time efficient, but weather, climate, and terrain might influence the results. Other challenges with such field tests could be to find the optimal pace throughout the run and to attain motivation for maximal effort for the entire test duration.[6]

An alternative test for assessing aerobic fitness in military personnel could be the 20 m shuttle run test (20 m SRT) as described by Léger et al.[7] The test is usually conducted indoors in a gymnasium, thereby reducing challenges related to outdoor testing. In addition, running speed is dictated during the test, thereby eliminating the chance of starting the test too fast or slow. Finally, the 20 m SRT is submaximal for much of its duration, so that maximal effort and motivation are only required in the last part of the test.[8]

Validity and reliability of the 20 m SRT are examined in several studies, but mainly in children,[7–10] adolescents,[7,11] and young adults.[6,7,12–18] The test is less validated in adults aged >30 years.[7,19] These previous studies generally demonstrate a relatively high correlation between the 20 SRT and $VO_{2max}$ directly measured and also a high correlation between repeated trials (reliability). However, to examine validity and reliability by correlation coefficients alone is not recommended, as correlation is mainly an indication of relationship (not agreement) and correlation coefficients are strongly influenced by the heterogeneity of the sample.[20]

Some previous studies have developed regression equations to predict $VO_{2max}$ from running performance in the 20 m SRT, but there is no general consensus about which equation predicts $VO_{2max}$ most accurately in adults.[12,13] Thus, it is not straightforward for the practitioner to decide which equation provides the most accurate estimation of $VO_{2max}$ for a specific group of subjects. Moreover, some countries use the 20 m SRT to evaluate aerobic fitness in their soldiers,[5] but neither information on validity and reliability of the 20 m SRT nor prediction equations for $VO_{2max}$ based on military personnel is to our knowledge yet published. Finally, no previous studies of the 20 m SRT have used a cross validation design with 2 independent samples of subjects analyzed separately, which we believe would generate valuable information on test validity.

Consequently, the objectives of this study were to (1) examine reliability and validity of the 20 m SRT test in military personnel; (2) develop a prediction equation suitable for estimating $VO_{2max}$ in military personnel; and (3) cross validate our new 20 m SRT equation in a second (independent) sample of soldiers, including a comparison against 5 existing equations developed on civilian adults.

## METHODS

### *Study Design and Ethics*

This validity and reliability study includes data from 2 different samples of subjects: Home Guard (HG) soldiers and Air

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Force (AF) cadets. Data collected on the HG soldiers were used to examine reliability of the 20 m SRT and to create a new equation for predicting $VO_{2max}$ from the 20 m SRT. Data collected on the AF cadets were used to cross validate our new prediction equation and the existing equations.

The study was approved by the Regional Committee for Medical and Health Research Ethics and the Norwegian Social Science Data Services. Subjects volunteered to participate by giving their written consent after receiving written and oral information about the study.

### *Measurements on Home Guard soldiers*

All male soldiers ($n$ = 59) in 2 regular HG troops were invited to the study, and 42 volunteered to participate (age 34.8 ± 4.0 years, weight 86.1 ± 12.1 kg, height 180.2 ± 6.1 cm, and body mass index 26.5 ± 3.1 $kg \cdot m^{-2}$). All measurements, except treadmill test, were conducted during a HG annual training in 2007. The annual training was not physically strenuous, and the soldiers were generally in a favorable state regarding nutrition, fluid, sleep, and exercise status during testing. Anthropometric measurements and the first 20 m SRT were completed on day 1. On the day after, all soldiers underwent a familiarization trial on the treadmill. On the third day, the retest of the 20 m SRT was carried out (1 subject withdrew; $n$ = 41). Direct measurement of $VO_{2max}$ was conducted between 1 and 2 weeks after the HG annual training (3 more subjects withdrew; $n$ = 38). The same 2 test leaders administered all measurements.

The 20 m SRT was conducted as described by Léger et al.[7] Briefly, the subjects ran back and forth between 2 lines 20 m apart, while running speed was dictated from CD audio bleeps. Initial speed was 8.5 $km \cdot h^{-1}$ and increased by 0.5 $km \cdot h^{-1}$ at every new level (every minute). Because running speed is very low in the first levels, no warm-up was administered before test. Between 5 and 7 subjects performed the test simultaneously indoor on a wooden floor. Temperature in the gymnasium was between 20 and 21°C. As most of the subjects had no earlier experience with running the 20 m SRT, and no habituation trial was administered, the test was thoroughly explained and demonstrated. In addition, the test leader always ran the first 2 levels together with the subjects to ensure that initial pace was set correctly. The test ended when the subject stopped running because of fatigue or when he was unable to reach the line on 3 consecutive occasions (≥3 m from the line). Results were registered as fully completed levels (ie, level 8), last half completed level (ie, level 8.5), and total shuttles attained (ie, 68 shuttles). Heart rate was monitored in all subjects during the test (S 610; Polar Electro OY, Kempele, Finland). The highest heart rate attained was defined as peak heart rate ($HR_{peak}$). A blood sample was taken from the fingertip 3 minutes post test in all subjects and analyzed for peak blood lactate ($BLa_{peak}$) (1500 Sport; YSI, Yellow Springs, Ohio). The lactate analyzer was calibrated once every hour with a 5 $mmol \cdot L^{-1}$ lactate standard, and linearity was controlled with a 15 $mmol \cdot L^{-1}$ standard.

Height and body weight were measured with a calibrated combined digital scale and stadiometer (model 708; Seca, Hamburg, Germany) to the nearest 0.1 kg and 0.5 cm, respectively. The familiarization trial on a treadmill was conducted similar to the real $VO_{2max}$ test, except that the subject stopped running 1–2 minutes before exhaustion.

Maximal oxygen uptake was measured directly in a mobile test laboratory placed at 2 locations in the HG soldiers' home area. Before running the $VO_{2max}$ test, subjects completed a warm up procedure consisting of 15 minutes low–moderate intensity running, 3 bouts of 30 seconds high-intensity running and stretching. The subject then attached nose clip and mouthpiece, the latter connected to a 3-way directional valve (model 2700; Hans Rudolf, Kansas City, Michigan). The test was performed on a treadmill (PPS 55 Sport; Woodway, Weil am Rhein, Germany) using a stepwise protocol with constant incline of 5.2%. Initial running speed for the first minute was set individually according to performance in the 20 m SRT, so that fatigue would be expected to occur within 4–7 minutes of running. Treadmill speed was automatically increased by 1 $km \cdot h^{-1}$ every minute until volitional exhaustion. Peak heart rate and $BLa_{peak}$ were measured as described for the 20 m SRT. Oxygen uptake was measured continuously with an online system (Oxycon Pro; Erich Jaeger, Hoechberg, Germany), using the mixing chamber mode set at 30 seconds sampling intervals. The average of the 2 highest consecutive measurements was defined as $VO_{2max}$. The online system was gas-calibrated with room air and certified calibration gases and volume calibrated manually with a 3-L syringe (Hans Rudolf) before every second test (once every hour). The laboratory was supplied with adequate ventilation through air conditioning, and the temperature in the laboratory was 22.1 ± 1.3°C. The $VO_{2max}$ test was accepted if 2 of the following criteria were met: (1) $HR_{peak}$ ≥ 95% of age-predicted $HR_{max}$ (220 $beats \cdot min^{-1}$ – age), (2) $BLa_{peak}$ ≥ 7 $mmol \cdot L^{-1}$, or (3) peak respiratory exchange ratio ($RER_{peak}$) ≥ 1.10. All HG soldiers produced an accepted $VO_{2max}$ test.

### *Measurements on Air Force Cadets*

All male first year cadets ($n$ = 30) at the Norwegian Air Force Academy volunteered to participate in the study. Two subjects were injured on the days of testing; hence 28 cadets were included in the study (age 23.3 ± 4.1 years, weight 78.4 ± 8.7 kg, height 179.2 ± 4.8 cm, and body mass index 24.4 ± 2.2 $kg \cdot m^{-2}$). All data were collected within 1 week in 2006. The 20 m SRT was carried out on day 1, using the same procedures as described for the HG soldiers and under similar conditions. The only difference was that $BLa_{peak}$ was not measured in the AF cadets. On day 2, anthropometric measurements and treadmill familiarization trial were conducted, as described for the HG soldiers. On day 3 and 4, $VO_{2max}$ was measured directly from treadmill running in the same mobile laboratory and with the same equipment and procedures used on the HG soldiers. All cadets produced an accepted test of $VO_{2max}$. The test leaders collecting data on the cadets were the same individuals who examined the HG soldier.

### Validation of Different 20 m SRT Equations

Validity of the new prediction equation developed in this study was compared with 5 published equations (1 of which actually uses a "table method") developed by other researchers (Table I). These 5 equations were selected because they were developed in samples of adults and are, therefore, relevant and comparable to those in this study.

### Statistical Analysis

Test–retest reliability was examined using mean difference ± 95% limits of agreement (LoA), intraclass correlation coefficient (ICC 3,1), and Pearson correlation coefficient (*r*). Validity was examined using the same statistical methods as for the reliability analysis. Differences between measured $VO_{2max}$ and estimated $VO_{2max}$ were analyzed with a paired sample *t* test. Differences between HG soldiers and AF cadets were analyzed with an independent sample *t* test. A simple linear regression model with measured $VO_{2max}$ as dependent variable was created. The following independent variables were included: age, height, $HR_{peak}$, and 20m SRT performance (expressed as last complete level, last half level (LHL), and total shuttles). The final multivariate model was built as described by Hosmer and Lemeshow,[21] and independent variables were excluded in a stepwise fashion if they did not reach the significance level. The underlying assumptions of the linear model, linearity, and constant residual variance were assessed by plotting residuals versus predicted values. The influence of co-linearity was assessed using the variance inflation factor and the Studentized deleted residuals. Cook's *d* was used to look for point of high influence.

Statistical analysis was performed in SPSS version 15.0 (SPSS, Chicago, Illinois) and in MedCalc version 11.1 (MedCalc Software, Mariakerke, Belgium). Level of significance was set at 0.05.

**TABLE I.** Equations Developed in Adults for Estimating $VO_{2max}$ from the 20 m SRT

| Study | Equation |
|---|---|
| Léger et al.[7] | $\hat{Y} = -24.4 + 6.0$ MAS |
| Ramsbottom et al.[6] | Table 3 |
| Léger and Gadoury[19] | $\hat{Y} = -32.678 + 6.592$ MAS |
| Stickland et al.[12] | $\hat{Y} = 2.75X + 28.8$ |
| Flouris et al.[13] | $\hat{Y} = (\text{MAS}6.65 - 35.8)0.95 + 0.182$ |

$\hat{Y}$, estimated maximal oxygen uptake in mL·kg⁻¹·min⁻¹; MAS, maximal aerobic speed; *X*, last half level (stage).

## RESULTS

The AF cadets performed significantly better on the 20 m SRT compared to the HG soldiers (Table II) and also produced a higher directly measured $VO_{2max}$ related to bodyweight (Table III).

### Reliability of the 20 m SRT

The HG soldiers completed on average 2.7 more shuttles in the retest compared to the first 20 m SRT ($p < 0.05$), and the LoA demonstrated a measurement error of ±10.1 shuttles (Table IV). This corresponds to an estimated $VO_{2max}$ of $-0.8 \pm 3.1$ mL·kg⁻¹·min⁻¹ between test and retest ($VO_{2max}$ estimated using our new equation, see next paragraph). Both ICC and Pearson *r* were between 0.95 and 0.96 for test–retest, irrespective of whether running performance in the 20 m SRT was expressed as total number of shuttles, LHL completed, or estimated $VO_{2max}$.

### Validity of the 20 m SRT

Data collected on the HG soldiers were used to develop a new equation for predicting $VO_{2max}$ from the 20 m SRT. The only factor that significantly contributed to the equation was running performance, expressed as last level completed (explained 63% of the variance in directly measured $VO_{2max}$), number of shuttles completed (explained 67% of the variance), or LHL completed (also explained 67% of the variance). The latter

**TABLE II.** Performance and Physiological Characteristics from the 20 m SRT in HG Soldiers ($n = 41$) and AF Cadets ($n = 28$)

| Subjects | Test/Retest | Shuttles (Number) | LHL Completed (Number) | Est. $VO_{2max}$ (mL·kg⁻¹·min⁻¹) | $HR_{peak}$ (beats·min⁻¹) | $BLa_{peak}$ (mmol·L⁻¹) |
|---|---|---|---|---|---|---|
| HG Soldiers | Test | 69.1 ± 18.9 | 8.6 ± 1.8 | 49.8 ± 5.0 | 188.0 ± 9.5 | 8.2 ± 1.6 |
| HG Soldiers | Retest | 71.8 ± 18.4* | 8.9 ± 1.7* | 50.6 ± 4.7* | 188.0 ± 8.9 | 8.6 ± 1.5* |
| AF Cadets | Test | 95.1 ± 11.4# | 11.0 ± 1.0# | 56.4 ± 2.7# | 200.4 ± 7.4# | NA |

NA, not available, Est. $VO_{2max}$ is based on our equation $\hat{Y} = 2.71X + 26.5$ (where *X* is LHL completed). *Significantly different than the first test ($p < 0.05$). #Significantly different than test and retest of HG soldiers ($p < 0.05$).

**TABLE III.** Performance Characteristics from Measurement of $VO_{2max}$ in Treadmill Testing of HG Soldiers ($n = 38$) and Cadets ($n = 28$)

| Subjects | $VO_{2max}$ (L·min⁻¹) | $VO_{2max}$ (mL·kg⁻¹·min⁻¹) | $RER_{peak}$ | $HR_{peak}$ (beats·min⁻¹) | $BLa_{peak}$ (mmol·L⁻¹) |
|---|---|---|---|---|---|
| HG soldiers | 4.24 ± 0.63 | 49.6 ± 6.3 | 1.14 ± 0.06 | 188.7 ± 8.7 | 8.7 ± 1.5 |
| AF cadets | 4.45 ± 0.57 | 56.8 ± 4.3* | 1.17 ± 0.08* | 198,6 ± 7.3* | 10.2 ± 1.4* |

*Significantly different compared to the HG soldiers ($p < 0.05$).

**TABLE IV.** Reliability Statistics of Performance and Estimated $VO_{2max}$ in 20 m SRT (Test and Retest) in HG Soldiers ($n = 41$)

| Test and Retest | Mean Difference ± 95% LoA | ICC | Pearson $r$ |
|---|---|---|---|
| Shuttles Completed (Number) | −2.7 ± 10.1 | 0.96 | 0.96 |
| LHL Completed | −0.3 ± 1.1 | 0.95 | 0.95 |
| Estimated $VO_{2max}$ (mL kg$^{-1}$ min$^{-1}$) | −0.8 ± 3.1 | 0.95 | 0.95 |

**TABLE V.** Validity Statistics Between Estimated $VO_{2max}$ (20 m SRT) and Measured $VO_{2max}$ (Treadmill) Using Different Prediction Equations on AF Cadets ($n = 28$)

| 20 m SRT Prediction Equations | Estimated $VO_{2max}$ Versus Directly Measured $VO_{2max}$ | | |
|---|---|---|---|
| | Mean Difference ± 95% LoA (mL·kg$^{-1}$·min$^{-1}$) | ICC ($r$) | Pearson ($r$) |
| Léger et al.[7] | −0.5 ± 6.3 | 0.66 | 0.68 |
| Ramsbottom et al.[6] | −5.7 ± 6.4 | 0.65 | 0.67 |
| Léger and Gadoury[19] | −0.8 ± 6.4 | 0.67 | 0.68 |
| Stickland et al.[12] | 2.4 ± 6.2 | 0.62 | 0.69 |
| Flouris et al.[13] | −5.6 ± 6.4 | 0.67 | 0.68 |
| New Equation (This Study) | −0.4 ± 6.2 | 0.62 | 0.69 |

factor was used to create the following equation: $\hat{Y} = 2.71X + 26.5$, where $\hat{Y}$ is predicted $VO_{2max}$ (mL·kg$^{-1}$·min$^{-1}$) and X is the LHL completed in the 20 m SRT.

Mean difference ± LoA between directly measured $VO_{2max}$ (treadmill test) and estimated $VO_{2max}$ (20 m SRT) was 0 ± 7.2 mL·kg$^{-1}$·min$^{-1}$ when our new equation was applied on the first 20 m SRT results of the HG soldiers. Equally, the ICC for estimated and measured $VO_{2max}$ was 0.80 and the Pearson correlation $r$ was 0.82.

### Validity of Different 20 m SRT Equations

Table V shows how measured $VO_{2max}$ agrees and correlates with estimated $VO_{2max}$ from the 20 m SRT using our new equation and the 5 alternative equations. There was no significant mean difference between measured $VO_{2max}$ and $VO_{2max}$ estimated from the 20 m SRT using the Léger et al.[7] equation ($p = 0.422$), the Léger and Gadoury[19] equation ($p = 0.190$), or our new equation ($p = 0.538$). The Ramsbottom et al.[6] table method and the Flouris et al.[13] equation significantly underestimated $VO_{2max}$ (both $p < 0.001$). The equation given by Stickland et al.[12] significantly overestimated $VO_{2max}$ ($p < 0.001$). There were only small differences between the equations regarding the magnitude of the 95% LoA, ICC, and Pearson $r$ for estimated and directly measured $VO_{2max}$.

## DISCUSSION

### Reliability of the 20 m SRT

The results indicate that the 20 m SRT is a reliable test for monitoring changes in aerobic-related fitness in military personnel. Mean difference ± LoA of number of shuttles completed was −2.7 ± 10.1, which corresponds to −0.8 ± 3.1 mL·kg$^{-1}$·min$^{-1}$ between test and retest. This is in line with the findings by Cooper et al.[16] who demonstrated that mean difference ± LoA for test–retest estimated $VO_{2max}$ was −0.4 ± 2.7 mL·kg$^{-1}$·min$^{-1}$ in their sample of 21 young active men. In a study by Lamb and Rogers,[18] the 20 m SRT was performed 3 times by 35 active young males and females. The mean difference ± LoA between trial 1 and 2 was −5.3 ± 16.3 shuttles, which corresponded to −1.1 ± 4.7 mL·kg$^{-1}$·min$^{-1}$. Between trial 2 and 3, the mean difference ± LoA was 0.0 ± 5.0 mL·kg$^{-1}$·min$^{-1}$. In other words, there was an increase in performance from trial 1 to trial 2, but no mean difference between trial 2 and trial 3. The tendency of performing slightly better in the retest might reflect a learning or habituation effect.[18,22] Our HG soldiers had no experience with running the 20 m SRT before the first test. Hence, such a learning effect is a possible reason for the small, but significant increase in performance seen from test to retest. We believe that our 0.8 mL·kg$^{-1}$·min$^{-1}$ higher retest estimated $VO_{2max}$ is of minor importance for most practical purposes.

Except for Cooper et al.[16] and Lamb and Rogers,[18] previous studies have mainly used Pearson correlation to describe reliability of the 20 m SRT. Although such an approach is not always recommended,[20] we included these numbers in this study for comparison purposes. Our study demonstrated a Pearson $r$ of 0.95–0.96 between test and retest, which is in line with previous studies of adults[7,22]. Our sample of HG soldiers could be regarded as relatively heterogeneous in terms of aerobic fitness, and this contributes to the high test–retest correlation coefficients seen in our material.

### Validity of the 20 m SRT

Our data showed that mean estimated $VO_{2max}$ from the 20 m SRT did not differ significantly from directly measured $VO_{2max}$ if using equations provided by Léger et al.,[7] Léger and Gadoury,[19] or this study. The equation by Stickland et al.[12] overestimated $VO_{2max}$, while the equation by Flouris et al.[13] and the table method by Ramsbottom et al.[6] underestimated $VO_{2max}$.

There might be several reasons why equations predict $VO_{2max}$ differently, even when gender and age are similar in the studies. First, the various equations have been developed in different samples, all with their unique features. Second, whether subjects attained their true maximal capacity during testing might vary among different studies. Finally, test conditions, protocols, and equipment could influence results. Concerning the latter, online metabolic analyzers might vary considerably to other analyzers and to the "gold standard" Douglas bag method even when correct calibration procedures are followed.[23] In our study, we did not perform any thorough comparison against the Douglas bag method. However, this is previously carried out by Foss and Hallén,[24] who concluded that the Oxycon Pro analyzer (similar to the one we used) is a very accurate system for measuring oxygen uptake. Regarding maximal exertion, we believe our subjects were close to their true maximal effort, as both mean $HR_{peak}$ and $BLa_{peak}$ were within generally accepted "true" maximal values.[25]

Validity of a test is not only about estimating a correct mean value in a sample, but also about the magnitude of measurement errors in single individuals. The 95% LoA demonstrated rather large variance between measured and estimated $VO_{2max}$ in HG soldiers as well as AF cadets. An example can be given: a cadet with a measured $VO_{2max}$ of about 56 $mL \cdot kg^{-1} \cdot min^{-1}$ will statistically have his $VO_{2max}$ estimated in the 20 m SRT to anywhere between approximately 49.5 and 62 $mL \cdot kg^{-1} \cdot min^{-1}$. Consequently, we believe that estimated $VO_{2max}$ from 20 m SRT should only be interpreted as a rather vague indication of measured $VO_{2max}$ in individuals.

When validity of the 20 m SRT is discussed, it should be emphasized that performance in 20 m SRT and directly measured $VO_{2max}$ is not the same. Performance in the 20 m SRT is definitely highly influenced by $VO_{2max}$, but also depends on anaerobic capacity, lactate threshold, fractional utilization of $VO_{2max}$, running economy, and the ability to tolerate high levels of fatigue.[26] In a military setting, it could be an advantage that a fitness test reflects the total performance in a type of work, and not only measured $VO_{2max}$. Hence, the 20 m SRT should not automatically be abandoned as a tool for assessing aerobic related fitness in military personnel simply because of the rather low validity of the 20 m SRT against directly measured $VO_{2max}$.

A relevant question for military practitioners is whether the 20 m SRT gives a valid estimate of performance in tests like the 2-mile run, the 12-minute run, or the 3,000-m run, and thereby could be used interchangeably with these types of field tests. The design in our study does not allow a clear answer to this. However, Ramsbottom et al.[6] demonstrated a higher correlation between the 20 m SRT and a 5 km run compared to the same 2 running tests against measured $VO_{2max}$ from treadmill running. Thus, we believe that performance in the 20 m SRT could give a good indication of performance in traditional military running tests.

### Strengths and Limitations of the Study

This study used a cross validation design to investigate validity of the 20 m SRT. The independent cross validation group consisted of AF cadets, who significantly differed from the HG soldiers (eg, higher aerobic fitness and lower age). We believe this design allows a more practical generalization compared to cross validation studies, where a group of subjects is randomly split into 2. The latter design will merely produce 2 similar cohorts, and any regression equation produced in the first cohort will usually match the second cohort more or less perfectly.

Many of the previous studies on validity and reliability of the 20 m SRT based their conclusions on inappropriate statistical methods.[18] In this study, we have included statistical analysis, which is generally regarded as more appropriate and informative, compared to correlation analysis alone.[20]

There are some limitations to the study as well. Even if the HG soldiers could be defined as a relatively heterogeneous group, the measured $VO_{2max}$ did cover only a range from 38 to 64 $mL \cdot kg^{-1} \cdot min^{-1}$. A sample with higher diversity regarding aerobic fitness would probably have produced a more precise and strong regression equation. Another limitation is that subjects were not given any habituation trial before the first 20 m SRT. As our prediction equation is created based on the results from the first trial of the 20 m SRT (not habituated subjects), a small overestimation of $VO_{2max}$ could be expected when conducting the 20 m SRT on subjects well habituated to the test. Finally, this study validated only the 20 m SRT in males. Consequently, the validity of our new equation is undetermined when applied to female military personnel.

### Practical Recommendations

On the basis of the previous studies and our results, we address a few recommendations to military (and civilian) practitioners. (1) The 20 m SRT should be considered a performance test (reflecting running performance with frequent turns), and not a test that necessarily reflects measured $VO_{2max}$ in individuals. (2) We recommend test results to be presented as LHL completed. This ensures higher accuracy and motivation among subjects, compared to last full level completed. (3) If estimating $VO_{2max}$ in military personnel is desired, we recommend that the equation given in this study or in the study by Léger et al.[7] or Léger and Gadoury[19] should be used. (4) For most practical purposes, a habituation trial is not necessary if the test is explained and demonstrated before the first trial. However, a small learning effect in the second trial should be expected. If using the 20 m SRT for research purposes, further practical recommendations are outlined in Tomkinson et al.[27]

## CONCLUSION

The 20 m SRT seems to be a reliable test for use in military personnel and could be used to detect relevant changes in performance related to aerobic fitness. The validity of the 20 m SRT is less certain, as relatively high variability was observed between measured $VO_{2max}$ and $VO_{2max}$ estimated from the 20 m SRT. If estimation of $VO_{2max}$ from the 20 m SRT is desired in military personnel, we recommend the practitioner to consider using one of the suggested equations presented in this study.

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# PAPER II

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# Validity and Reliability of Bioelectrical Impedance Analysis and Skinfold Thickness in Predicting Body Fat in Military Personnel

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**ABSTRACT** Previous studies show that body composition is related to injury risk and physical performance in soldiers. Thus, valid methods for measuring body composition in military personnel are needed. The frequently used body mass index method is not a valid measure of body composition in soldiers, but reliability and validity of alternative field methods are less investigated in military personnel. Thus, we carried out test and retest of skinfold (SKF), single frequency bioelectrical impedance analysis (SF-BIA), and multifrequency bioelectrical impedance analysis measurements in 65 male and female soldiers. Several validated equations were used to predict percent body fat from these methods. Dual-energy X-ray absorptiometry was also measured, and acted as the criterion method. Results showed that SF-BIA was the most reliable method in both genders. In women, SF-BIA was also the most valid method, whereas SKF or a combination of SKF and SF-BIA produced the highest validity in men. Reliability and validity varied substantially among the equations examined. The best methods and equations produced test–retest 95% limits of agreement below ±1% points, whereas the corresponding validity figures were ±3.5% points. Each investigator and practitioner must consider whether such measurement errors are acceptable for its specific use.

## INTRODUCTION

A favorable body composition has been shown to be related to lower injury risk[1] and higher physical performance[2] in military personnel. Consequently, body composition is often evaluated in individuals before selection for military service and education. In-service evaluation of soldiers' body composition could also be relevant, because military service may well alter body composition, as seen from basic military training,[3] shorter intense military training courses,[4] or from international missions.[5] To optimize selection of prospective soldiers, and for precise in-service evaluation of soldiers' occupational readiness, health and nutritional status, reliable and valid body composition test methods should be applied to the individual soldier.

Body mass index (BMI) is used by some military systems when screening and selecting prospective soldiers.[6,7] Although BMI is a quick and easy proxy for body composition, it might be inaccurate on the individual level.[8] One of the main problems of using BMI is that it does not differentiate between muscle mass and fat mass, i.e., an athletic person with high levels of muscle mass might be classified as overweight. Thus, alternative methods for assessing body composition in military personnel should be evaluated.

Underwater weighing, hydrometry, dual-energy X-ray absorptiometry (DXA) and magnetic resonance imaging are among the body composition methods considered valid and often referred to as reference methods.[9,10] Such laboratory methods are time consuming, expensive, and not available for most military units. Thus, quicker and cheaper field methods are necessary for military settings. Skinfold (SKF) measurements and bioelectrical impedance analysis (BIA) might be two such alternative field methods for use on soldiers. The SKF method is based on the principle that there is a relationship between subcutaneous body fat (SKF thickness) and total body fat.[11] Measurement of SKF thickness at standardized anthropometrical sites is used to predict body density (BD), from which fat-free mass (FFM) or percent body fat (% BF) can be calculated using one of the many available prediction equations. The BIA method is based on the principle that electric current flows at different rates through the body depending on its composition.[12] The impedance measures (resistance, R and reactance, Xc) are used to predict total body water, FFM, or % BF from various equations. The BIA method uses either a single-frequency bioelectrical impedance analysis (SF-BIA) or a multifrequency bioelectrical impedance analysis (MF-BIA) instrument to measure body composition.[13]

Validity and reliability of SKF and BIA as tools for evaluating body composition have been frequently studied, but with divergent conclusions.[14] This might be because of the use of different reference methods, prediction equations, study populations, and statistical methods. Furthermore, it has been suggested that a sufficient variety of prediction equations has already been established, and that future studies should focus on cross validating existing equations on the specific population of interest.[15] For military populations,

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This study has not previously been presented or published internationally. However, some of the data have been presented in a master thesis (written in Norwegian) at the Norwegian School of Sport Sciences, Oslo, 2010: Holtberget, K. Validering av måleinstrumenter for kroppssammensetning.

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we have identified few studies published within the three last decades in which SKF and/or BIA methods have been validated against an acknowledged reference method. Kremer et al[16] found that validity of an SF-BIA device was not superior to a circumference method for predicting % BF in U.S. Air Force members. In a second study, Lintsi et al[17] predicted % BF in male conscripts and found a higher correlation coefficient for SKF against DXA compared to hand-to-hand SF-BIA against DXA. In addition, Friedl et al[3] found that selected SKF and circumference-based equations performed equally well in terms of validity in female soldiers, but that none of the equations were very accurate in detecting change in % BF (sensitivity). Studies on reliability of body composition field methods in military personnel seem to be even scarce.

Thus, the aim of this study has been to examine test–retest reliability and criterion-related validity of the SKF method, the SF-BIA method, a combined SF-BIA and SKF method, and the MF-BIA method in predicting % BF in male and female soldiers.

## METHODS

### Study Design and Ethics

Reliability of SKF and BIA measurements was evaluated in a test–retest design, whereas validity of SKF and BIA to predict % BF was evaluated by comparisons to the reference method DXA. The study was approved by the Regional Committee for Medical and Health Research Ethics and the Norwegian Social Science Data Services. Subjects volunteered to participate by giving their written consent after receiving written and oral information about the study.

### Subjects

All first-year military cadets (39 men and 6 women) at the Royal Norwegian Air Force Academy volunteered for the study. In addition, 20 female military recruits and officers from Ørland Main Air Station gave consent to participate. Mean age (±SD and range) for the 39 men and 26 women was 22 ± 2 (19 – 27) and 21 ± 4 (18 – 30) years, respectively. All subjects were of Caucasian origin.

### Measurements

All data were collected within three consecutive days for each subject. Twenty-four to 48 hours were allocated between test and retest measurements. The DXA scans were conducted at St. Olavs Hospital in Trondheim by trained staff. SKF and BIA measurements were administered locally at the military bases by three researchers (A.Aa, K.H, and R.H), each responsible for the same measurements during all data gathering. Data were collected in the morning from 7:00 a.m. until noon. Before all measurements, the subjects followed a standardization strategy that included ≥8 hours of fasting, ≥8 hours of no physical training, and ≥2 hours of no coffee or smoking. The subjects were allowed to drink water ad libitum before testing. Five of the women participated in the study during menstrual cycle. Temperature during all BIA and SKF measurements was between 19 and 21°C.

Height and body weight (BW) were measured with a combined digital scale and stadiometer (Seca model 708; Seca GmbH, Hamburg, Germany) to the nearest 0.1 kg and 5 mm, respectively. As subjects were measured wearing T-shirt and shorts, 0.3 kg was subtracted from the measured BW. The scale was calibrated with 40 to 80 kg of weight plates (Eleiko Sport AB, Halmstad, Sweden) before the test period.

DXA scans were performed on a Hologic Discovery A (Hologic, Bedford, Massachusetts) using the auto whole-body fan-beam mode with results analyzed using software version 12.7.3.1:3. Two days after the first scan, 12 randomly chosen cadets (9 men and 3 women) were re-scanned to investigate DXA test–retest reliability.

The RJL Quantum II (RJL Systems, Clinton Township, Michigan) was used to measure SF-BIA (50 kHz). The BIA device was calibrated once a day with a 500 ohm (Ω) test resistor. Testing was carried out as explained elsewhere,[18] and according to manufacturer instructions. FFM was calculated according to the equations given in Table I. Percent BF was then calculated as follows: % BF = ([BW – FFM]/BW) × 100.

The InBody 720 (Biospace Co., Seoul, Korea) was used to measure MF-BIA (1–1000 kHz). Testing was conducted according to manufacturer instructions. The subject stepped on the foot electrodes barefoot and stood still until BW was measured (BW subtracted by 0.3 kg because subjects wore shorts and T-shirt). The subject grasped the hand electrode cables, and gently held on to the thumb electrode and the palm electrode. Hands were held ~15° away from the body, until measurements were completed. The inbuilt software was used to calculate % BF and other body composition values.

SKF thickness was measured with a Harpenden caliper (John Bull, British Indicators Ltd., West Sussex, UK) at seven sites for men and six sites for women (Table II). Anatomical location of the sites was according to Heyward and Wagner[33] and Lohman et al,[34] and always on the right side of the body. The sites were marked with a nonpermanent marking pen, so that the sites had to be relocated for the retest. Two measurements were taken at each site. If the second measure differed by more than 0.2 mm from the first reading, a third measure was taken. The average of the two closest measurements was recorded. The equations presented in Table I were used to calculate BD or % BF. The Siri equation was used to calculate % BF from BD: % BF = (4.95/BD – 4.5) × 100.

### Selection of Prediction Equations

Numerous equations exist for predicting body composition from SKF and SF-BIA measurements. We have only included equations developed and validated on populations similar to ours (pertaining to age, gender, ethnicity, and a normal/athletic body composition). In addition, our SKF equations depend on

**TABLE I.** Selected Equations for Predicting BD, FFM or % BF From SKF and/or BIA Measurements in Adult Men (m) and Women (w)

| Method | Prediction Equation |
|---|---|
| SKF | |
| Durnin and Womersley[19] (m) | $BD = 1.1765 - 0.0744 \cdot \log \Sigma1$ |
| Durnin and Womersley[19] (w) | $BD = 1.1567 - 0.0717 \cdot \log \Sigma1$ |
| Jackson and Pollock[20] (m) | $BD = 1.1125025 - 0.0013125 \cdot \Sigma2 + 0.0000055 \cdot \Sigma2^2 - 0.0002440 \cdot A$ |
| Jackson and Pollock[20] (w) | $BD = 1.089733 - 0.0009245 \cdot \Sigma3 + 0.0000025 \cdot \Sigma3^2 - 0.0000979 \cdot A$ |
| Jackson et al[21] (m) | $BF = 0.2568 \cdot \Sigma4 - 0.0004 \cdot \Sigma4^2 + 4.8647$ |
| Jackson et al[21] (w) | $BF = 0.4446 \cdot \Sigma4 - 0.0012 \cdot \Sigma4^2 + 4.3387$ |
| Lohman[11] (m) | $BD = 1.0982 - 0.000815 \cdot \Sigma5 + 0.00000084 \cdot \Sigma5^2$ |
| Slaughter et al[22] (m) | $BF = 1.21 \cdot \Sigma6 - 0.008 \cdot \Sigma6^2 - 5.5$ |
| Slaughter et al[22] (w) | $BF = 1.33 \cdot \Sigma6 - 0.013 \cdot \Sigma6^2 - 2.5$ |
| SF-BIA | |
| Deurenberg et al[23] (m + w) | $FFM = 0.340 \cdot H^2/R - 0.127 \cdot A + 0.273 \cdot BW + 4.56 \cdot G1 + 0.1534 \cdot H - 12.44$ |
| Gray et al[24] (m) | $FFM = 0.00139 \cdot H^2 - 0.0801 \cdot R + 0.187 \cdot BW + 39.830$ |
| Gray et al[24] (w) | $FFM = 0.00151 \cdot H^2 - 0.0344 \cdot R + 0.140 \cdot BW - 0.158 \cdot A + 20.387$ |
| Kotler et al[25] (m) | $FFM = 0.50 \cdot (H^{1.48}/R^{0.55}) \cdot (1.0/1.21) + 0.42 \cdot BW + 0.49$ |
| Kotler et al[25] (w) | $FFM = 0.88 \cdot (H^{1.97}/R^{0.49}) \cdot (1.0/22.22) + 0.081 \cdot BW + 0.07$ |
| Kyle et al[26] (m + w) | $FFM = 0.518 \cdot H^2/R + 0.231 \cdot BW + 0.130 \cdot Xc + 4.229 \cdot G1 - 4.104$ |
| Lohman[15] (m) | $FFM = 0.485 \cdot H^2/R + 0.338 \cdot BW + 5.32$ |
| Lohman[15] (w) | $FFM = 0.476 \cdot H^2/R + 0.295 \cdot BW + 5.49$ |
| Lukaski et al[27] (m) | $FFM = 0.827 \cdot H^2/R + 5.214$ |
| Lukaski et al[27] (w) | $FFM = 0.821 \cdot H^2/R + 4.917$ |
| Segal et al GEN [28] (m) | $FFM = 0.00132 \cdot H^2 - 0.04394 \cdot R + 0.30520 \cdot BW - 0.16760 \cdot A + 22.66827$ |
| Segal et al GEN [28] (w) | $FFM = 0.00108 \cdot H^2 - 0.02090 \cdot R + 0.23199 \cdot BW - 0.06777 \cdot A + 14.59453$ |
| Segal et al FSE [28] (m) | $FFM = 0.0006636 \cdot H^2 - 0.02117 \cdot R + 0.62854 \cdot BW - 0.12380 \cdot A + 9.33285$ |
| Segal et al FSE [28] (w) | $FFM = 0.00064602 \cdot H^2 - 0.01397 \cdot R + 0.42087 \cdot BW + 10.43485$ |
| Sun et al[29] (m) | $FFM = 0.65 \cdot H^2/R + 0.26 \cdot BW + 0.02 \cdot R - 10.68$ |
| Sun et al[29] (w) | $FFM = 0.69 \cdot H^2/R + 0.17 \cdot BW + 0.02 \cdot R - 9.53$ |
| van Loan et al[30] (m + w) | $FFM = 0.51 \cdot H^2/R + 0.33 \cdot BW + 1.69 \cdot G2 + 3.66$ |
| SKF and SF-BIA | |
| Guo et al[31] (m) | $BF = -0.2790 \cdot H^2/R + 0.6316 \cdot T + 0.3464 \cdot BW + 1.5034$ |
| Yannakoulia et al[32] (w) | $FFM = 0.391 \cdot BW + 0.168 \cdot H - 0.253 \cdot T + 0.144 \cdot H^2/R - 9.49$ |
| MF-BIA | |
| InBody 720 equation (m + w) | Unknown, in-built manufacturer equation |

BD, body density; BF, percent body fat; FFM, fat-free mass; GEN, generalized equation; FSE, fatness specific equation; A, age (years); H, height (cm); R, resistance (ohm); Xc, reactance (ohm); BW, body weight (kg); G1, gender (man = 1, woman = 0); G2, gender (man = 1, woman = −1); T, triceps SKF (mm); Σ1, sum of triceps + biceps + subscapular + suprailiac SKF (mm); Σ2, sum of chest + triceps + subscapular SKF (mm); Σ3, sum of triceps + suprailiac + abdominal SKF (mm); Σ4, sum of triceps + suprailiac + thigh SKF (mm); Σ5, sum of triceps + abdominal + subscapular SKF (mm); Σ6, sum of triceps + subscapular SKF (mm).

a maximum of four SKF sites and the equations are "generalized."[20] Our selection of SF-BIA equations is based on reviews in this field made by Kyle et al[35] and Houtkooper et al,[36] including only prediction equations developed using a traditional 50 kHz device. We have also included two studies that validated equations combining SF-BIA and a one-site SKF measure. The prediction equation for % BF from the MF-BIA device is not known, because it is not released by the manufacturer. Thus, results from the MF-BIA measurements are based on the preset equation for this device.

### *Statistical Analysis*

Test–retest reliability was examined using mean difference ±95% limits of agreement (LoA) including Bland–Altman plots and intraclass correlation coefficient (ICC 3,1–single measures) with 95% confidence interval (CI). Validity was examined using the same statistical methods as for the reliability analysis, in addition to Pearson correlation coefficient (*r*). Data from the first tests (no retest data) were used to evaluate validity. Differences between test–retest measurements, and among % BF measured from DXA and the various field methods, were analyzed with a paired sample *t* test. Differences between men and women were analyzed with an independent sample *t* test. All statistical analyses were performed in SPSS (version 18.0; IBM Corporation, Armonk, New York), except for the LoA analysis for which MedCalc (version 12.1.4; MedCalc Software bvba, Ostend, Belgium) was used. A probability (*p*) of <0.05 was considered statistically significant.

## RESULTS

### *Descriptive Results*

Descriptive characteristics for the participating subjects in test and retest are shown in Table II. Men were significantly different from women in all measured values at first test, except for BMI ($p = 0.06$) and Xc ($p = 0.10$). Mean DXA measured % BF were 10% points lower in men compared to

**TABLE II.** Descriptive Characteristics of Body Composition Measurements at Test and Retest. Results Presented as Means (SD)

| | Men ($n$ = 39) | | Women ($n$ = 26) | |
|---|---|---|---|---|
| Variable | Test | Retest | Test | Retest |
| Height (cm) | 183.0 (6.5) | 183.0 (6.5) | 167.0 (6.0) | 167.0 (5.5) |
| Body Weight (kg) | 80.3 (10.2) | 80.1 (10.2)* | 63.1 (8.4) | 63.1 (8.4) |
| BMI (kg m$^{-2}$) | 24.0 (2.5) | 23.9 (2.5) | 22.7 (2.9) | 22.7 (2.9) |
| SKF | | | | |
| Triceps (mm) | 11.3 (4.1) | 11.7 (4.3)* | 19.6 (4.9) | 19.5 (4.2) |
| Biceps (mm) | 5.1 (1.7) | 5.5 (2.0)* | 11.6 (4.7) | 11.4 (3.9) |
| Abdominal (mm) | 18.8 (6.3) | 20.5 (7.5)* | 27.5 (7.4) | 27.7 (7.1) |
| Suprailiac (mm) | 16.7 (4.9) | 19.6 (7.4)* | 23.3 (9.6) | 22.6 (8.2) |
| Thigh (mm) | 13.8 (5.6) | 14.6 (5.9)* | 28.0 (8.8) | 28.0 (7.5) |
| Subscapular (mm) | 11.0 (2.9) | 11.6 (3.3)* | 14.1 (6.5) | 14.1 6.8) |
| Chest (mm) | 6.5 (2.1) | 6.6 (2.1) | N/A | N/A |
| SF-BIA | | | | |
| Resistance, $R$ (Ω) | 467 (45) | 467 (45) | 563 (58) | 565 (57) |
| Reactance, Xc (Ω) | 65 (6) | 65 (6) | 67 (6) | 67 (7) |
| MF-BIA | | | | |
| Body Weight (kg) | 80.3 (10.3) | 80.1 (10.2)* | 63.3 (8.4) | 63.3 (8.4) |
| Fat Free Mass (kg) | 69.2 (7.5) | 69.0 (7.5) | 48.0 (4.9) | 48.1 (4.7) |
| Body Fat (kg) | 11.1 (4.4) | 11.1 (4.6) | 15.3 (5.8) | 15.3 (5.9) |
| Body Fat (%) | 13.5 (4.5) | 13.6 (4.8) | 23.7 (6.4) | 23.5 (6.5) |
| DXA[a] | | | | |
| Body Weight (kg) | 81.1 (10.2) | 80.7 (11.8) | 64.3 (8.6) | 64.9 (7.6)* |
| Fat Free Mass (kg) | 68.2 (7.4) | 68.2 (8.2) | 47.6 (4.8) | 48.5 (2.6) |
| Bone Mineral Density (g cm$^{-2}$) | 1.20 (0.09) | 1.17 (0.04) | 1.11 (0.07) | 1.16 (0.04) |
| Body Fat (kg) | 12.9 (4.1) | 12.5 (4.4) | 16.7 (5.0) | 16.4 (6.7) |
| Body Fat (%) | 15.6 (3.7) | 15.1 (3.4) | 25.6 (4.7) | 24.8 (7.5) |

N/A, not available. *$p < 0.05$ between test and retest. [a]DXA retest sample consists of only 9 men and 3 women.

women. In men, six out of seven SKF sites were measured to be significantly thicker at retest compared to the first test.

### Reliability

Reliability statistics of the different methods and equations for men and women are presented in Table III and IV, respectively.

In men, the average test–retest measurement error (95% LoA) was ±2.5% points BF in the five SKF equations, whereas the corresponding figure was ±2.0% points for the ten SF-BIA equations. The LoA for the combined SKF & SF-BIA equation and the MF-BIA device was ±1.4% and ±2.3%, respectively. Among all methods and equations applied on men, the smallest LoA was seen for the SF-BIA fatness specific equation (FSE) by Segal et al (Fig. 1A). All SKF equations predicted % BF to be significantly higher in the retest compared to the first test.

In women, the average test–retest LoA for % BF was ±3.2% points in the 4 SKF equations, whereas the corresponding figure was ±1.7% points for the 10 SF-BIA equations. The LoA for the combined SKF and SF-BIA equation and the MF-BIA device was ±1.8% and ±2.6%, respectively. The smallest LoA was seen for the SF-BIA Segal et al FSE (Fig. 1B).

Figure 2 shows test–retest measurements for DXA. Mean difference ±95% LoA was −0.1 ± 0.8% BF, whereas ICC (95% CI) was 1.00 (0.99–1.00) for DXA test–retest.

### Validity

Tables V and VI show validity statistics of the different methods and equations for men and women, respectively.

In men, the average LoA for predicted % BF in the five SKF equations (when compared to DXA) was ±4.2% points, whereas the corresponding figure was ±5.4% points for the ten SF-BIA equations. The MF-BIA device and the combined SF-BIA and SKF equation produced smaller LoA and higher $r$ and ICC against DXA, compared to all SF-BIA equations. Among all methods and equations, the smallest LoA was observed for the SKF equation by Jackson et al (Fig. 1C).

In women, the average LoA for predicted % BF in the four SKF equations (when compared to DXA) was ±5.7% points, whereas the corresponding figure was ±5.6% points for the ten SF-BIA equations. The MF-BIA device and the combined SF-BIA and SKF equation produced a LoA comparable to the average SKF and SF-BIA measurement error. Among all methods and equations, the SF-BIA equation by Kyle et al produced the smallest LoA, but the equation significantly overestimated % BF by 2.5% points (Fig. 1D).

## DISCUSSION

This study sought to evaluate reliability and validity of body composition field methods based on SKF and BIA in predicting % BF in military personnel. The data revealed that reliability and validity varied substantially among equations.

**TABLE III.** Reliability Statistics (Test–Retest) for Predicted Percent Body Fat From SKF and BIA Measurements in 39 men. Ranked According to 95% LoA Within Each Method Category

| Method | Mean Difference ± 95% LoA (% BF) | ICC (95% CI) |
|---|---|---|
| SKF | | |
| Jackson and Pollock[20] | −0.4 ± 1.3* | 0.98 (0.96– 0.99) |
| Slaughter et al[22] | −0.8 ± 2.0* | 0.98 (0.97– 0.99) |
| Lohman[11] | −0.9 ± 2.6* | 0.95 (0.90– 0.97) |
| Jackson et al[21] | −1.2 ± 3.1* | 0.88 (0.78– 0.94) |
| Durnin and Womersley[19] | −1.4 ± 3.5* | 0.91 (0.84– 0.95) |
| SF-BIA | | |
| Segal et al FSE [28] | 0 ± 0.7 | 0.99 (0.98– 0.99) |
| Kotler et al[25] | 0 ± 1.1 | 0.99 (0.98– 0.99) |
| Segal et al GEN[28] | 0 ± 1.4 | 0.99 (0.98– 0.99) |
| Deurenberg et al[23] | 0 ± 1.5 | 0.99 (0.97– 0.99) |
| Lohman[15] | 0 ± 2.1 | 0.97 (0.94– 0.98) |
| Van Loan et al[30] | 0 ± 2.2 | 0.97 (0.94– 0.98) |
| Kyle et al[26] | 0.1 ± 2.2 | 0.97 (0.95– 0.99) |
| Sun et al[29] | 0 ± 2.3 | 0.97 (0.94– 0.98) |
| Gray et al[24] | 0 ± 2.4 | 0.97 (0.95– 0.99) |
| Lukaski et al[27] | 0 ± 3.6 | 0.96 (0.93– 0.98) |
| SKF and SF-BIA | | |
| Guo et al[31] | −0.3 ± 1.4* | 0.99 (0.98– 0.99) |
| MF-BIA | | |
| InBody 720 equation | −0.1 ± 2.3 | 0.97 (0.94– 0.98) |

GEN, generalized equation; FSE, fatness specific equation. *$p < 0.05$ for mean difference between test and retest.

**TABLE IV.** Reliability Statistics (Test–Retest) for Predicted Percent Body Fat From SKF and BIA Measurements in 26 Women. Ranked According to 95% LoA Within Each Method Category

| Method | Mean Difference ± 95% LoA (% BF) | ICC (95% CI) |
|---|---|---|
| SKF | | |
| Slaughter et al[22] | −0.1 ± 2.0 | 0.96 (0.90– 0.98) |
| Durnin and Womersley[19] | 0.1 ± 3.2 | 0.94 (0.87– 0.97) |
| Jackson and Pollock[20] | 0.1 ± 3.5 | 0.93 (0.86– 0.97) |
| Jackson et al[21] | 0.1 ± 4.2 | 0.92 (0.83– 0.96) |
| SF-BIA | | |
| Segal et al FSE[28] | −0.1 ± 0.8 | 0.99 (0.99– 1.00) |
| Segal et al GEN[28] | −0.1 ± 1.2 | 0.99 (0.99– 1.00) |
| Deurenberg et al[23] | −0.1 ± 1.3 | 0.99 (0.98– 1.00) |
| Lohman[15] | −0.2 ± 1.6 | 0.99 (0.97– 0.99) |
| Sun et al[29] | −0.2 ± 1.7 | 0.99 (0.98– 1.00) |
| Van Loan et al[30] | −0.2 ± 1.7 | 0.98 (0.96– 0.99) |
| Gray et al[24] | −0.1 ± 1.8 | 0.99 (0.98– 1.00) |
| Kotler et al[25] | −0.1 ± 1.8 | 0.99 (0.98– 1.00) |
| Kyle et al[26] | −0.1 ± 2.0 | 0.98 (0.96– 0.99) |
| Lukaski et al[27] | −0.3 ± 2.8 | 0.98 (0.96– 0.99) |
| SKF and SF-BIA | | |
| Yannakoulia et al[32] | 0 ± 1.8 | 0.99 (0.97– 0.99) |
| MF-BIA | | |
| InBody 720 equation | 0.2 ± 2.6 | 0.98 (0.95– 0.99) |

GEN, generalized equation; FSE, fatness specific equation. *$p < 0.05$ for mean difference between test and retest.

### SKF Method

Reliability of the SKF method was generally slightly lower (wider LoA and lower ICC) compared to the other methods investigated. In men, validity of the SKF method was generally higher (smaller LoA, higher ICC and *r*) than the SF-BIA method, whereas the opposite was evident for women. Validity of the SKF method was comparable to that observed for the combined SKF and SF-BIA and the MF-BIA method.

Among the SKF equations for men, the Jackson and Pollock equation showed the smallest test–retest measurement error (LoA), but also a large underestimation of % BF when compared to DXA. The Jackson et al equation demonstrated high validity, but lower reliability. Thus, in men, no SKF equation was clearly superior to the others when both reliability and validity are accounted for. In women, the equation by Slaughter et al demonstrated higher reliability compared to the other SKF equations. It was also the only equation that showed no mean difference in estimated % BF when compared to DXA. However, the Slaughter et al equation produced the lowest correlation (ICC and *r*) against DXA, and had the second widest LoA (±6.0%) for predicting % BF. Hence, similar to men, no single SKF equation for women was superior to the other equations on both reliability and validity.

Major advantages of the SKF method are that it uses a simple instrument, measurements can easily be carried out in the field, it is relatively quick, and it is resistant to fast changes in hydration status.[37,38] Conversely, a major drawback is that rather extensive training is needed to obtain reliable measurements.[10,38] In our male subjects, SKF thickness was measured to be significantly higher in all but one SKF sites during retest compared to the first test. Hence, all male SKF equations predicted % BF to be higher in the retest. This finding is most likely because of a systematic error made by the operator, and illustrates that accurate and precise SKF measurements might be difficult to obtain. All men were measured during the first week, whereas most women were measured during the second week. This might explain why the systematic error appeared only in data points for men. Thus, SKF reliability for the male subjects should be evaluated with some caution. Still, this study demonstrated that reliability for the SKF method was in accordance with previous data for both men and women.[39]

### SF-BIA Method

Reliability of the SF-BIA method was generally higher compared to the SKF method. Most SF-BIA equations also showed higher reliability compared to the MF-BIA method. Among women, four SF-BIA equations produced smaller LoA (higher validity) for estimated % BF against DXA, when compared to all other methods and equations. On the contrary, most of the male SF-BIA equations produced wider LoA (lower validity) compared to other methods and equations investigated.

No single SF-BIA equation stood out as superior to all other equations when both reliability and validity were considered. Yet, for both men and women the Segal et al FSE produced the smallest test–retest LoA among all the methods

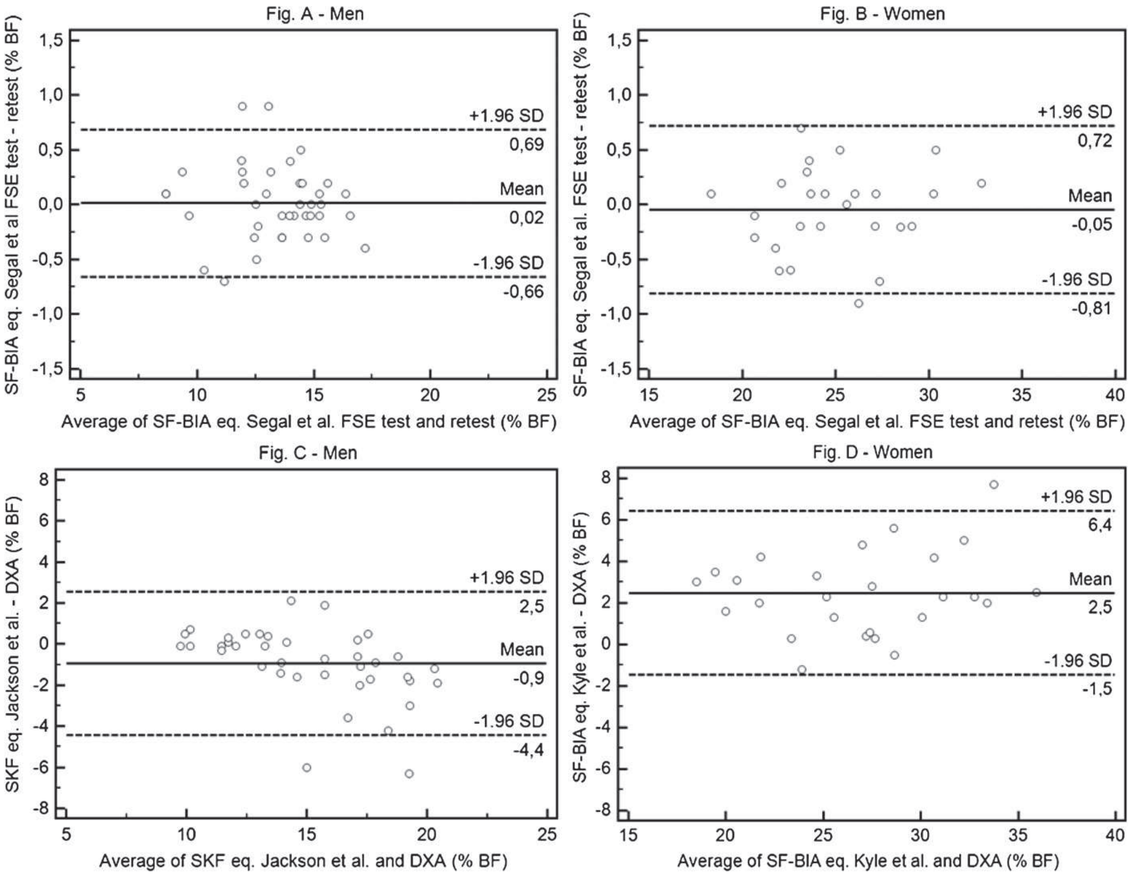


**FIGURE 1.** Bland–Altman plots with mean difference ± 95% LoA for reliability and validity of selected methods for predicting % BF. (A) Test–retest reliability of SF-BIA using equation by Segal et al (fatness specific equation [FSE]) in men. (B) Test–retest reliability of the SF-BIA using equation by Segal et al (FSE) in women. (C) Validity of SKF using equation by Jackson et al in men. (D) Validity of SF-BIA using equation by Kyle et al in women.

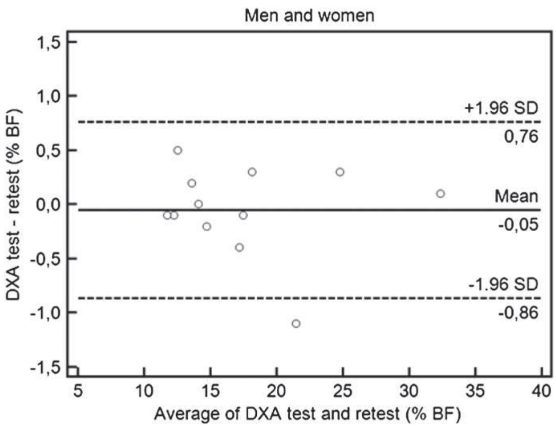


**FIGURE 2.** Bland–Altman plot with mean difference ± 95% LoA for % BF measured by DXA in first test and retest (*n* = 12).

and equations scrutinized. The Segal et al FSE is primarily developed for use among men and women below 20% BF and 30% BF, respectively.[28] Because most of our subjects demonstrated % BF values within these limits, this might be one of the reasons why this equation produced the smallest test–retest LoA.

Although the SF-BIA Segal et al FSE demonstrated the smallest test–retest LoA, other SF-BIA equations demonstrated higher validity. The Lohman equation (for men) showed no mean difference in estimated % BF compared to DXA, and relatively small LoA. The Lohman equation also produced small LoA against DXA in women, but % BF was underestimated by 1.9% points. Overall, the SF-BIA method (e.g., Lohman equation) might be recommended in female soldiers, because it scored high on both reliability and validity. Validity for the SF-BIA equations with the smallest LoA was comparable to previous findings by Williams and Bale.[40] The latter study demonstrated a slightly higher validity for the

**TABLE V.** Validity Statistics for Predicted Percent Body Fat From SKF and BIA Measurements Against Percent Body Fat Measured with DXA in 39 Men. Ranked According to 95% LoA Within Each Method Category

| Method | Mean Difference ± 95% LoA (% BF) | ICC (95% CI) | Pearson *r* |
|---|---|---|---|
| SKF | | | |
| Jackson et al[21] | −0.9 ± 3.5* | 0.85 (0.74– 0.92) | 0.88 |
| Durnin and Womersley[19] | 3.4 ± 3.7* | 0.87 (0.77– 0.93) | 0.87 |
| Lohman[11] | −1.3 ± 3.9* | 0.86 (0.74– 0.92) | 0.86 |
| Jackson and Pollock[20] | −4.8 ± 4.8* | 0.87 (0.76– 0. 93) | 0.87 |
| Slaughter et al[22] | 1.6 ± 5.2* | 0.82 (0.69– 0.90) | 0.87 |
| SF-BIA | | | |
| Kotler et al[25] | 2.2 ± 4.4* | 0.81 (0.66– 0.89) | 0.81 |
| Lohman[15] | −0.1 ± 4.7 | 0.82 (0.68– 0.90) | 0.83 |
| Kyle et al[26] | 3.5 ± 4.7* | 0.84 (0.72– 0.91) | 0.87 |
| Van Loan et al[30] | −1.6 ± 4.9* | 0.81 (0.67– 0.90) | 0.83 |
| Segal et al FSE[28] | −2.2 ± 4.9* | 0.66 (0.43– 0.80) | 0.76 |
| Deurenberg et al[23] | 4.4 ± 5.1* | 0.80 (0.64– 0.89) | 0.81 |
| Sun et al[29] | 1.1 ± 5.2* | 0.80 (0.66– 0.89) | 0.83 |
| Segal et al GEN[28] | 0.3 ± 5.7 | 0.76 (0.59– 0.87) | 0.78 |
| Gray et al[24] | 4.2 ± 5.9* | 0.78 (0.62– 0.88) | 0.83 |
| Lukaski et al[27] | 2.9 ± 8.5* | 0.69 (0.48– 0.82) | 0.82 |
| SKF and SF-BIA | | | |
| Guo et al[31] | 0.6 ± 3.6* | 0.90 (0.82– 0.95) | 0.92 |
| MF-BIA | | | |
| InBody 720 equation | −2.1 ± 3.9* | 0.89 (0.79– 0.94) | 0.90 |

GEN, generalized equation; FSE, fatness specific equation. *$p < 0.05$ for mean difference between prediction equation and DXA.

**TABLE VI.** Validity Statistics for Predicted Percent Body Fat From SKF and BIA Measurements Against Percent Body Fat Measured With DXA in 26 Women. Ranked According to 95% LoA Within Each Method Category

| Method | Mean Difference ± 95% LoA (% BF) | ICC (95% CI) | Pearson *r* |
|---|---|---|---|
| SKF | | | |
| Jackson and Pollock[20] | 2.3 ± 4.7* | 0.88 (0.75– 0.95) | 0.88 |
| Jackson et al[21] | 3.6 ± 5.4* | 0.86 (0.71– 0.93) | 0.87 |
| Slaughter et al[22] | 0.4 ± 6.0 | 0.73 (0.49– 0.87) | 0.77 |
| Durnin and Womersley[19] | 6.6 ± 6.6* | 0.88 (0.75– 0.94) | 0.88 |
| SF-BIA | | | |
| Kyle et al[26] | 2.5 ± 4.0* | 0.92 (0.82– 0.96) | 0.92 |
| Lohman[15] | −1.9 ± 4.2* | 0.90 (0.79– 0.96) | 0.90 |
| Van Loan et al[30] | −2.5 ± 4.2* | 0.90 (0.78– 0.95) | 0.90 |
| Deurenberg et al[23] | 3.2 ± 4.6* | 0.88 (0.74– 0.94) | 0.88 |
| Segal et al FSE[28] | −0.7 ± 5.2 | 0.80 (0.60– 0.91) | 0.84 |
| Sun et al[29] | −0.5 ± 5.3 | 0.87 (0.74– 0.94) | 0.89 |
| Segal et al GEN[28] | 0.8 ± 5.8 | 0.83 (0.66– 0.92) | 0.84 |
| Gray et al[24] | −3.2 ± 7.3* | 0.80 (0.60– 0.91) | 0.85 |
| Kotler et al[25] | −2.1 ± 7.5* | 0.80 (0.60– 0.90) | 0.87 |
| Lukaski et al[27] | 0.9 ± 8.0 | 0.80 (0.60– 0.91) | 0.90 |
| SKF and SF-BIA | | | |
| Yannakoulia et al[32] | 1.8 ± 5.3* | 0.86 (0.71– 0.93) | 0.86 |
| MF-BIA | | | |
| InBody 720 equation | −1.9 ± 5.2* | 0.89 (0.77– 0.95) | 0.93 |

GEN, generalized equation; FSE, fatness specific equation. *$p < 0.05$ for mean difference between prediction equation and DXA.

SKF method compared to the SF-BIA method for both male and female athletes. However, Lukaski et al[27] found the opposite in a heterogeneous sample of adult men and women. Thus, although reliability generally seems to be somewhat higher for BIA methods compared to SKF methods,[38] no clear conclusion is given in the literature on whether BIA or SKF produce the highest validity.[10,15]

Our results showed clearly that picking the right SF-BIA equation is crucial, as measurement error varied substantially between different equations. As an example, three of the female SF-BIA equations produced a LoA of ≥ ±7% BF against DXA. If predicting % BF to be 20% in a woman using one of these equations, the investigator must account for that her true % BF is somewhere between 13 and 27% BF.

In most cases, such high measurement error is not acceptable, and other methods or equations should be used.

There are several advantages of the SF-BIA method. The method is quick, the instrument is relatively cheap to purchase and use, the instrument is small and mobile, it is easy to operate, and testing can be carried out without the subject undressing. The drawback is that the test conditions should be standardized to get normal hydration levels, which mean that dietary intake and physical exercise should be controlled before measurement.[12] Such standardization could be difficult to obtain in military settings.

### Combined SF-BIA and SKF Method

Reliability of the combined SF-BIA & SKF method was generally higher compared to the other methods, although some SF-BIA equations produced smaller test–retest LoA in both men and women. In men, the Guo et al equation produced higher ICC and *r* against DXA compared to all other methods, and also the second smallest LoA. Hence, this equation seems to be a good option for male soldiers, because it scored high on both reliability and validity. However, in women, validity of the Yannakoulia et al equation was not higher than the other methods and equations.

One disadvantage of the combined method is that both SKF and BIA measurements must be obtained. Yannakoulia et al concluded that adding SKF to the SF-BIA equation only reduced the measurement error slightly, and actually recommended to not add the SKF measurement.[32] Yet, both the female and male equations are based on only one SKF site (triceps), which is a quick and relatively easy (low inter-tester variability[41]) site to measure. Thus, the combined method is probably faster and easier to carry out compared to traditional 4-sites SKF measurements. Other pros and cons of this method should be similar to those previously explained for SKF and SF-BIA.

### MF-BIA Method

The MF-BIA method (InBody 720) produced wider test–retest LoA when compared to several SF-BIA and SKF equations. Validity of the MF-BIA device was higher than that observed for all SF-BIA equations in men, but not in women. The InBody 720 underestimated % BF against DXA by approximately 2% in both men and women. This is in line with previous findings by Völgyi et al.[42]

The InBody 720 is user friendly, both for the operator and the person tested. Within a few minutes, the machine displays results for several body composition factors, such as % BF, visceral fat, muscle balance between right/left side and upper/lower body, and total skeleton muscle mass. The latter is important in a performance/military context, but could also be calculated from the SF-BIA method.[43] Compared to the SF-BIA device, the InBody 720 is more expensive and less portable. In addition, it is not possible to use other algorithms than the one that is preset. As for the SF-BIA method, standardization of dietary intake and physical exercise is important.

### Study Limitations

In validation studies, a basic assumption is that the reference method must be accurate and precise, so that the indirect method could be compared against “true” figures. However, there is no universally accepted “gold standard” methodology within body composition research.[10] DXA is a much used reference method in body composition validation studies, but has some limitations. The DXA algorithm assumes a constant hydration of the FFM, which is not always true.[29] In addition, different DXA machines and software might produce significantly different figures for the various body composition components.[44] Nevertheless, DXA is usually considered a reasonably precise whole-body method,[10] and a method that produces highly reliable measurements of BF.[44] The latter was verified through our own test–retest DXA measurements.

Our male SKF measurements were significantly higher at six out of seven sites during retest compared to the first test. As mentioned, this was probably because of a systematic error made by the operator. This fault does not only influence reliability but also validity for the male SKF measures. This systematic error exemplifies that SKF measurements could be difficult to obtain accurately, even among relatively experienced test leaders. This should be taken into account when selecting a body composition field method for use on soldiers.

A great number of prediction equations for estimating FFM and BF exist for both SF-BIA and SKF measurements. We have selected some of the most used equations, and equations that have been developed in similar populations as our soldiers. Still, we might have overlooked some equations that could have performed equally well, or better, compared to our selected equations.

Kremer et al[16] suggested that circumference-based equations predict % BF as accurately as BIA in military personnel. Our study examined only SKF and BIA out of several existing body composition field methods. Thus, we cannot determine whether other field methods could have performed better in estimating % BF in military personnel. Friedl et al[45] also recommended circumference measurements in large-scale military screenings, because it is an easier measurement for nontechnical users. The choice of a body composition field method should therefore not exclusively depend on measurement error obtained under more optimized research settings.

This study was conducted on soldiers with a normal/athletic body composition and with age ranging from 19 to 30 years. In addition, all subjects were of Caucasian origin. Because equations for SKF and BIA have been shown to be population specific,[15] our results should not be generalized to all type of military personnel, e.g., subjects that are older, less fit, or of a different ethnicity.

## CONCLUSION

This study found that none of the body composition methods investigated was clearly superior to other methods, because the results varied according to gender, which equation was used, and whether the focus was on reliability versus validity. However, in women, some SF-BIA equations were both more reliable and valid (smaller LoA, higher ICC and *r*) than the other methods and equations. In male soldiers, we think the combined SKF and SF-BIA method (Guo et al equation) could be recommended in personnel with similar demographics to the study group, when both reliability and validity are considered. In all methods, a relatively large measurement error (wide LoA) against DXA must be accounted for at the individual level. Selection of an appropriate SKF or BIA equation to predict % BF is crucial, because both validity and reliability might vary greatly from one equation to another.

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PAPER III

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# Anthropometrics, Body Composition, and Aerobic Fitness in Norwegian Home Guard Personnel

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## Abstract

Aandstad, A, Hageberg, R, Holme, IM, and Anderssen, SA. Anthropometrics body composition and aerobic fitness in Norwegian Home Guard personnel. *J Strength Cond Res* 28(11): 3206–3214, 2014—The Norwegian Home Guard (HG) consists of soldiers and officers who primarily live a civilian life but are typically called in for military training a few days per year. Although full-time soldiers and officers are monitored annually on physical fitness, no such assessments are performed on regular HG personnel. Data on physical fitness of similar forces from other nations are also scarce. Thus, the main aim of this study was to collect reference data on physical fitness in HG personnel. A total of 799 male soldiers and officers from the regular and the rapid reaction HG force participated in this study. Between 13 and 19% of the subjects were obese, according to measured body mass index, waist circumference and estimations of body fat. The mean (95% confidence interval) estimated peak oxygen uptake from the 20-m shuttle run test was 50.1 (49.7–50.6) $mL\cdot kg^{-1}\cdot minute^{-1}$. Personnel from the rapid reaction force had a more favorable body composition compared with the regular HG personnel, whereas no differences were found for peak oxygen uptake. The physical demands on HG personnel are not well defined, but we believe that the majority of Norwegian HG soldiers and officers have a sufficient aerobic fitness level to fulfill their planned HG tasks. The gathered data can be used by military leaders to review the ability of the HG to perform expected military tasks, to serve as a future reference material for secular changes in HG fitness level, and for comparison purposes among similar international reserve forces.

**Key Words** military, Army, reservist, oxygen uptake, physical fitness, Norway

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## Introduction

Traditionally, a relatively high level of physical fitness has been warranted in soldiers, justified by potentially high physical workloads in both military training and warfare (20). The military today has access to various forms of motorized transportation besides new and efficient technology and equipment, but it is claimed that the physical demands placed on modern soldiers continue to be substantial (22,28). Thus, physical fitness is still an emphasized and valued attribute in the armed forces worldwide. Aerobic capacity ($\dot{V}O_2max$), body composition, muscular strength, and muscular endurance are major components of the term "physical fitness" (21). Favorable test scores on such fitness components are associated with increased military performance and reduced injury risk (15,16,20). Consequently, Norwegian full-time soldiers and officers must perform physical fitness tests at least once a year. However, most reserve Home Guard (HG) personnel (soldiers and officers) are excepted from this regime.

The Norwegian HG consists of approximately 45,000 soldiers and officers from 11 HG districts. The soldiers have previously completed mandatory basic military training, whereas the officers have completed military officer training. The regular (REG) personnel are called in for obligatory military training 3–7 days per year, whereas approximately 5,000 soldiers and reserve officers volunteer for a more comprehensive service of 15–20 days of military training per year in the rapid reaction (RAP) force. Thus, most HG personnel are civilians in their daily life.

The HG is responsible for not only the military defense of the territory of Norway but also supports the police and the civilian society during crisis and natural disasters (12). The HG consists of both sea and land personnel and completes many similar tasks as fulltime soldiers in the Army and the Navy. Thus, HG soldiers might have to perform possibly physically challenging tasks like casualty evacuations, ship boarding, loaded marching, and heavy manual material handling, besides less demanding activities like establishing road checkpoints and securing buildings. The HG also assists in natural disasters and rescue operations, where physical demands vary among the various operations. However, empiric data on HG soldiers' job demand are lacking, and

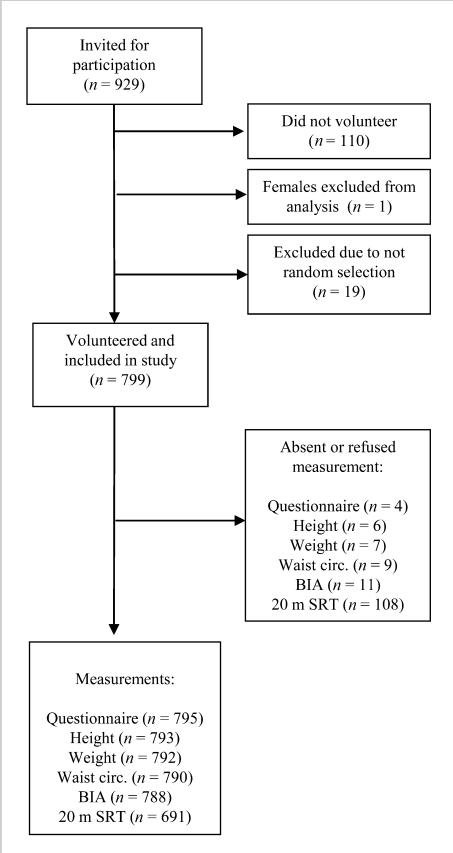


**Figure 1.** Flowchart of test order, participation, and drop-out.

it is therefore not clear how often and to what extent HG soldiers perform physically hard work during service.

Home Guard personnel must pass physical fitness tests to be accepted for service in the RAP-HG force because this service is considered more physically challenging than the REG-HG service. The REG-HG personnel are not tested on any fitness parameters during their HG career. It might be argued that fitness level should not be much lower in HG personnel compared with full-time soldiers and officers because they all work in close cooperation in real-scenario crisis and warfare on home territory. However, similar to the job demand analysis, no data related to physical fitness have previously been reported in Norwegian HG personnel. Moreover, reports on physical fitness of comparable forces (National Guard, HG, Reservists, etc.) from other nations are also scarce. Yet, Warr et al. (35) recently presented such data on the U.S. Arizona National Guard soldiers. They concluded that National Guard soldiers had higher percent body fat (BF), equal maximal oxygen uptake ($\dot{V}O_2max$), and higher maximal strength, compared with full-time active duty U.S. soldiers. Physical fitness has also been reported on large samples of Finnish reserve soldiers (11,34). However, the Finnish and the American soldiers differ from our HG personnel in some aspects such as military training frequency and recruitment process. Hence, the various study populations might not be directly comparable. The lack of knowledge about physical fitness levels in reserve military personnel has been acknowledged in previous literature, and increased research into health, physical fitness, and readiness of reservists has been recommended (35,37).

Thus, the primary aim of this study was to present reference values for anthropometrics, body composition, and aerobic capacity in Norwegian HG soldiers and officers. The body composition measurements also allowed us to estimate muscle mass, which is an important determinant of muscle strength (18). The presented reference values will be discussed in relation to physical demands within the HG and

**Table 1.** Anthropometrical characteristics of HG personnel (divided on HG force).*†‡

| HG force | Height (cm) | Body weight (kg) | BMI (kg·m$^{-2}$) | WC (cm) |
|---|---|---|---|---|
| REG-HG ($n$ = 702–704) | 180.0 (179.5 to 180.5) | 85.0 (84.0 to 85.9) | 26.2 (25.9 to 26.4) | 94.5 (94.0 to 95.5) |
| RAP-HG ($n$ = 88–89) | 181.5 (180.0 to 183.0) | 83.9 (80.9 to 87.0) | 25.4 (24.7 to 26.2) | 91.5 (89.5 to 93.5) |
| Total ($n$ = 790–793) | 180.5 (180.0 to 180.5) | 84.8 (83.9 to 85.8) | 26.1 (25.8 to 26.3) | 94.0 (93.5 to 95.0) |
| Adjusted difference (95% CI) | 0 (−2.0 to 2.5) | 0 (−3.7 to 3.6) | −0.1 (−1.1 to 0.8) | −1.5 (−4.0 to 1.5) |
| $p$-value | 0.830 | 0.979 | 0.772 | 0.301 |

*Data are presented as mean (95% CI).
†Differences are adjusted for age, HG district, and military rank, and reflect RAP-HG minus REG-HG.
‡HG = Home Guard; BMI = body mass index; WC = waist circumference; REG = regular; RAP = rapid reaction; CI = confidence interval.

**Table 2.** Body composition and bioelectrical impedance analysis in HG personnel (divided on HG force).*†‡

| HG force | Resistance (ohm) | Reactance (ohm) | FFM (kg) | SMM (kg) | BF (kg) | BF (%) |
|---|---|---|---|---|---|---|
| REG-HG ($n$ = 700) | 454 (451 to 458) | 61 (61 to 61) | 67.5 (66.9 to 68.1) | 35.6 (35.3 to 35.9) | 17.5 (17.0 to 18.0) | 20.0 (19.6 to 20.4) |
| RAP-HG ($n$ = 88) | 442 (433 to 452) | 60 (59 to 62) | 68.9 (66.9 to 70.8) | 37.1 (36.3 to 38.0) | 14.9 (13.3 to 16.4) | 17.2 (16.0 to 18.3) |
| Total ($n$ = 788) | 453 (450 to 456) | 61 (60 to 61) | 67.6 (67.1 to 68.2) | 35.8 (35.5 to 36.0) | 17.2 (16.7 to 17.7) | 19.7 (19.3 to 20.1) |
| Adjusted difference (95% CI) | −23 (−35 to −10) | −4 (−5 to −2) | 2.2 (−0.1 to 4.4) | 1.6 (0.6 to 2.7) | −2.4 (−4.4 to −0.4) | −2.9 (−4.5 to −1.3) |
| $p$-value | <0.001 | 0.001 | 0.057 | 0.003 | 0.021 | 0.001 |

*Differences are adjusted for age, HG district, and military rank, and reflect RAP-HG minus REG-HG.
†Data are presented as mean (95% CI).
‡HG = Home Guard; FFM = fat-free mass; SMM = skeletal muscle mass; BF = body fat; REG = regular; RAP = rapid reaction; CI = confidence interval.

compared with physical fitness values previously reported in regular and reserve soldiers and officers.

## Methods

### Experimental Approach to the Problem

This study is a descriptive cross-sectional study with a cluster-randomized sampling procedure. The main aim of this study was to present reference values for physical fitness in a nationally representative sample of Norwegian HG personnel. The primary outcome variables were body mass index (BMI), waist circumference (WC), BF, fat-free mass (FFM), skeletal muscle mass (SMM), and peak oxygen uptake ($\dot{V}O_2$peak). These variables were selected based on their association with endurance capacity, muscular strength, and military-related physical performance.

### Subjects

The study was approved by the Regional Committee for Medical and Health Research Ethics and the Norwegian Social Science Data Services. Subjects volunteered to participate by giving their written consent after receiving written and oral information about the study.

The sampling procedure started by allocating all 13 HG districts (only 11 districts exist today) into 5 groups, based on geographical location: North, South, East, West, and Mid Norway. One HG district from each stratification group was randomly selected to participate in this study. All 5 selected HG districts accepted the invitation. Each HG district was visited twice between years 2006 and 2009 during scheduled military HG training. Between 2 and 6 troops were randomly selected to participate at each visit. A total of 38 troops were included in the study, and 4 of these troops consisted of RAP-HG personnel. The participating RAP-HG soldiers and officers were recruited from HG districts located in the West and Mid Norway, whereas the REG-HG personnel were recruited from all the 5 districts.

All available soldiers and officers (928 men, 1 woman) in the selected 38 troops received information about the study and were invited to participate. One hundred ten subjects (12%) declined to participate, whereas 19 subjects were later excluded because of inappropriate randomization. Because there was only 1 female subject, her data have been excluded from the analysis. Thus, 799 men (89 belonging to the RAP-HG force) volunteered and met the inclusion criteria (Figure 1). However, 108 subjects (including 13 RAP-HG subjects) declined to participate in the running test (or were absent during testing), and a few did not complete various anthropometrical measurements and the questionnaire (Figure 1). Within the RAP-HG sample, 7 of the subjects were full-time officers (work 100% for the Norwegian HG), 26 were reserve HG officers (civilians, but act as officers during scheduled HG training), and 56 were private HG soldiers (civilians, but act as soldiers during scheduled HG training). Within the REG-HG sample, 69 were reserve HG officers, whereas 641 were private HG soldiers. In our analysis, subjects were categorized as either RAP-HG

**TABLE 3.** Aerobic fitness from the 20-m shuttle run test in HG personnel (divided on HG force).*†‡

| HG force | Total shuttles (no.) | Last half level (no.) | $\dot{V}O_2$peak ($mL\cdot kg^{-1}\cdot min^{-1}$) | $HR_{peak}$§ ($b\cdot min^{-1}$) |
|---|---|---|---|---|
| REG-HG ($n = 614$) | 69 (68 to 71) | 8.5 (8.5 to 9.0) | 49.9 (49.4 to 50.3) | 190 (189 to 191) |
| RAP-HG ($n = 77$) | 78 (74 to 83) | 9.5 (9.0 to 10.0) | 52.1 (51.0 to 53.3) | 192 (189 to 194) |
| Total ($n = 691$) | 70 (69 to 72) | 8.5 (8.5 to 9.0) | 50.1 (49.7 to 50.6) | 190 (189 to 191) |
| Adjusted difference (95% CI) | 3 (−4 to 10) | 0 (−0.5 to 1.0) | 0.7 (−1.2 to 2.5) | 0 (−4 to 3) |
| *p*-value | 0.401 | 0.478 | 0.475 | 0.972 |

*Differences are adjusted for age, HG district and military rank, and reflect RAP-HG minus REG-HG.
†HG = Home Guard; Est.$\dot{V}O_2$peak = estimated peak oxygen uptake; $HR_{peak}$ = peak heart rate; REG = regular; RAP = rapid reaction; CI = confidence interval.
‡Data are presented as mean (95% CI).
§Heart rate data from 37 REG-HG subjects and 17 RAP-HG subjects were missing because of monitor interference or technical faults.

personnel (which includes RAP-HG soldiers and officers) or REG-HG personnel (which includes REG-HG soldiers and officers). We also categorized the subjects as either private soldiers (from both HG forces) or officers (from both HG forces; includes full-time and reserve officers).

Age ranged from 18 to 44 years among the subjects. Mean (range) age for the REG-HG and RAP-HG personnel were 33 (18–44) and 28 (20–44) years, respectively. If dividing the subjects according to rank, the mean (range) age of the private soldiers and officers were 32 (18–44) and 32 (20–44) years, respectively.

#### Procedures

For each individual subject, all measurements were performed within 1 day during HG military training. The measurements took place indoors in sport halls located at the military base or nearby community. All data were collected by the 2 same test leaders (A.A. and R.H.) throughout the project.

Body weight and height were measured using a calibrated combined digital scale and stadiometer (model 708; Seca Corp., Hamburg, Germany) to the nearest 0.1 kg and 5 mm, respectively. The subject removed the shoes before measurement, and 0.2–0.5 kg were subtracted from the weight measurements because subjects wore light sport clothing. Body mass index was calculated by dividing weight (in kilograms) by height (in meters) squared. The individual BMI values have been classified according to the established cutoff values (36).

Waist circumference was measured twice with a tape measure to the nearest 0.5 cm at the line of the umbilicus after a normal exhalation. The mean value of the 2 measurements was used in the analysis. The individual WC values were classified according to the established cutoff values for men (36). We define the term "anthropometrics" to include body weight, height, BMI, and WC.

Body composition was estimated from bioelectrical impedance analysis (BIA) with a single frequency device (Quantum III RJL Systems Inc., Clinton Township, MI, USA). Testing was performed as previously described (1), except that no standardization regarding nutrition was followed before measurements and that testing was conducted at any time during the day. Fat-free mass was estimated from the equation derived by Sun et al. (32): $FFM\ (kg) = 0.65 \times height^2/resistance + 0.26 \times body\ weight + 0.02 \times resistance - 10.68$. Body fat in kilograms was calculated from subtracting FFM from body weight, whereas %BF was calculated from dividing BF (in kilograms) by body weight. Skeletal muscle mass was estimated from the equation by Janssen et al. (19): $SMM\ (kg) = 0.401 \times height^2/resistance + 3.825 - 0.071 \times age + 5.102$.

Aerobic capacity was measured from the 20-m shuttle run test (20-m SRT), as described by Léger et al. (23). The subjects ran back and forth between 2 lines 20 m apart, whereas running speed was dictated from compact disc audio bleeps. Initial speed was 8.5 $km\cdot h^{-1}$ and increased by 0.5 $km\cdot h^{-1}$ at every new level (every minute). No warm-up was administered before test. After a thorough explanation of the test procedure, the subjects performed the test while typically running in groups of 5–12 people. The test leader always ran the first 2 levels together with the subjects to ensure that initial pace was set correctly. The test ended when the subject stopped running because of fatigue or when he was unable to reach the line on 3 consecutive occasions (≥3 m from the line). Results were registered as total shuttles achieved (1 shuttle equals 1 × 20 m) and the nearest last half level (LHL) achieved. As an example, a subject who ran 2 shuttles at level 8 attained 8.0 LHL (totally 62 shuttles), whereas a subject who ran 7 shuttles into level 8 attained 8.5 LHL (totally 67 shuttles). Peak oxygen uptake was calculated from the equation $\dot{V}O_2peak\ (mL\cdot kg^{-1}\cdot min^{-1}) = 2.71\ LHL + 26.5$. This equation is derived from a subgroup of our REG-HG soldiers who performed the 20-m SRT and direct measurements of $\dot{V}O_2$max from treadmill running (2). We will use the term $\dot{V}O_2$peak because all results have been included in the analysis, and we cannot be sure that all subjects reached their true maximal effort during test (26). Heart

**Table 4.** Selected anthropometrical, body composition, and 20-m shuttle run characteristics and results in HG officers ($n$ = 84–101) and private soldiers ($n$ = 591–669).

| Rank | BMI ($kg \cdot m^{-2}$) | WC (cm) | BF (%) | SMM (kg) | Total shuttles (no.) | Est. $\dot{V}O_2peak$ ($mL \cdot kg^{-1} \cdot min^{-1}$) |
|---|---|---|---|---|---|---|
| Private soldiers | 26.1 (25.8 to 26.4) | 94.5 (93.7 to 95.2) | 19.8 (19.4 to 20.3) | 35.7 (35.4 to 35.9) | 69 (67 to 71) | 49.8 (49.3 to 50.3) |
| Officers | 25.7 (25.2 to 26.3) | 92.5 (90.8 to 94.2) | 18.7 (17.8 to 19.6) | 36.3 (35.5 to 37.0) | 79 (74 to 83) | 52.3 (51.1 to 53.4) |
| Adjusted difference (95% CI) | −0.4 (−1.2 to 0.4) | −2.0 (−4.1 to 0.2) | −0.6 (−1.8 to 0.6) | 0.1 (−0.7 to 1.0) | 9 (3 to 14) | 2.2 (0.9 to 3.5) |
| $p$-value | 0.375 | 0.075 | 0.357 | 0.729 | 0.001 | 0.001 |

Data are presented as mean (95% CI).
Differences are adjusted for age, HG district, and HG force, and reflect officers minus private soldiers.
HG = Home Guard; BMI = body mass index; WC = waist circumference; BF = body fat; SMM = skeletal muscle mass; Est. $\dot{V}O_2peak$ = estimated peak oxygen uptake; CI = confidence interval.

rate was monitored (at 5-second sampling intervals) in all subjects during the test (S 610; Polar Electro OY, Kempele, Finland). The highest value attained was defined as peak heart rate ($HR_{peak}$). Heart rate data from 54 subjects (8%) were excluded because of monitor interference or technical faults.

#### Statistical Analyses

All outcome variables, including their residuals, were checked for normality by visual inspections of data distribution plots. A linear mixed-effect model with the restricted maximum likelihood approach and LSD confidence interval (CI) adjustments was used to check for differences between groups, REG-HG vs. RAP-HG and officers vs. private soldiers, and for the missing data analysis. The mixed model allowed us to account for the cluster-randomized design using troop as a random effect. Analyses were adjusted for age and HG district when checking for differences between groups. In addition, we adjusted for military rank when assessing differences between REG-HG and RAP-HG personnel and we adjusted for HG force when checking for differences between officers and private soldiers. No adjustments were made during the missing data analysis. Some of the anthropometrical and body composition variables and residuals were slightly skewed. When analyzing differences between groups after log transforming these variables, the $p$ values changed only marginally and no conclusions were altered. Thus, all presented statistics were based on untransformed data. Values are presented as mean (95% CI), if not otherwise stated. Statistical analyses were performed in SPSS (version 21). A $p$-value of $\leq$ 0.05 was considered statistically significant.

### Results

Anthropometrical characteristics for Norwegian HG personnel are presented in Table 1. There were no significant differences in height, weight, BMI, and WC between RAP-HG and REG-HG personnel, after adjusting for age, HG district, and military rank. Among all HG personnel, 12.7% had a BMI $\geq$30.0 $kg \cdot m^{-2}$, whereas 19.3% had a WC $\geq$102.0 cm.

Body composition characteristics are presented in Table 2. The RAP-HG personnel had significantly higher SMM and lower BF (in percentage and kilograms, respectively) compared with the REG-HG personnel.

The 20-m SRT produced a mean estimated $\dot{V}O_2peak$ at around 50 $ml \cdot kg^{-1} \cdot min^{-1}$ in Norwegian HG personnel (Table 3). After adjusting for age, HG district, and military rank, no significant differences in running performance or estimated $\dot{V}O_2peak$ were found between RAP-HG and REG-HG personnel. HG officers achieved 2.2 $ml \cdot kg^{-1} \cdot min^{-1}$ higher estimated $\dot{V}O_2peak$ compared with the private soldiers (Table 4). Yet, no significant differences in any of the anthropometrical or body composition variables were observed between officers and private soldiers. The missing data analysis revealed no significant difference in anthropometrics or body composition between HG personnel who ran the 20-m SRT and those

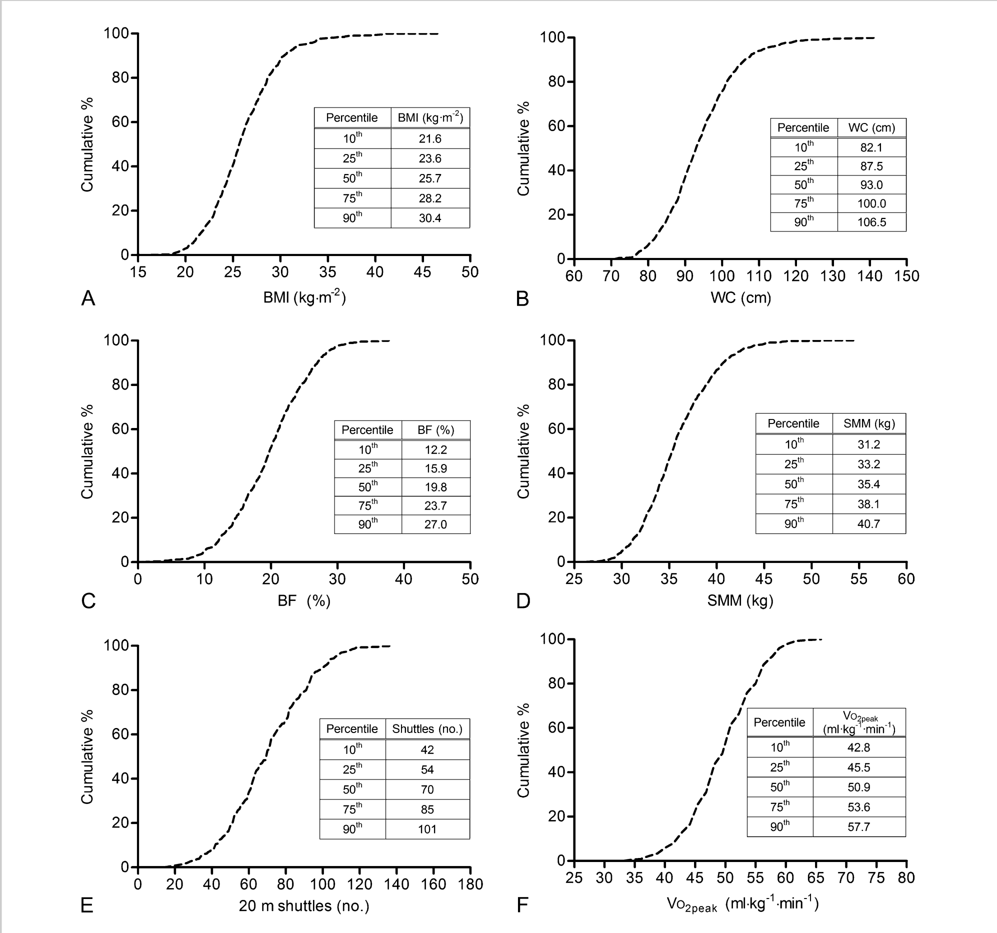


**Figure 2.** Cumulative relative frequency (%) for selected anthropometrical, body composition, and aerobic fitness variables in HG personnel. A) BMI = body mass index (*n* = 792), B) WC = waist circumference (*n* = 790), C) BF = body fat in percent (n = 788), D) SMM = skeletal muscle mass (n = 788), D) BF = body fat in percent (*n* = 788), E) 20-m shuttles = number of shuttles in the 20-m shuttle run test (*n* = 691), F) $\dot{V}O_2$peak = estimated peak oxygen uptake (*n* = 691).

who did not participate in the running test. The cumulative relative frequency for selected anthropometrical, body composition, and aerobic fitness variables are shown in Figure 2.

## Discussion

This study has presented reference material for anthropometrics, body composition, and aerobic fitness in Norwegian HG personnel. The results showed that 13–19% of the personnel were obese, according to the established cutoff values for BMI and WC, whereas mean estimated $\dot{V}O_2$peak was about 50 $ml \cdot kg^{-1} \cdot min^{-1}$. Differences related to type of HG force or military rank were generally small or nonexisting.

It is claimed that body composition might not be a strong predictor of soldiers' performance, as long as values are within a wide range of healthy values (13). Other studies conclude that high FFM mass does relate to high load-bearing capability, low FFM to increased injury risk, whereas fatness is related to lower endurance capacity (13,28). Thus, FFM and %BF seem to have some relevance related to overall performance in soldiers (17). In addition, both WC and BMI are well-established anthropometric measures with established thresholds for healthy range values (36). Although BMI is criticized for not differentiating between muscle and fat mass in individuals and for being a proxy method for BF, it has merit as an indicator of health at the group level (31). Thus, data on anthropometrics and body composition give valuable information about health and fitness of military personnel.

Our data showed that RAP-HG personnel generally had a more desirable body composition compared with REG-HG personnel. This difference might be because of the RAP-HG force selection process, where soldiers and officers have to pass physical fitness tests. However, we did not observe any differences in anthropometrics or body composition between HG officers and private soldiers. This was a bit surprising since officers earlier in their military career have been selected based on physical fitness.

It is not common to identify body composition demands related to specific military tasks. To better understand how body composition values in our HG soldiers compare with military prerequisites, the U.S. Army BF standards could be used (13). The U.S. Army upper limits of %BF vary according to age, from 20 to 26% for male soldiers. Using these limits, 75 and 88% of the REG-HG and RAP-HG personnel, respectively, were within the desired %BF levels. Civilian health recommendations are primarily related to BMI and WC and less to %BF (31,36). Our results showed that 12.7% of the HG personnel had BMI $>30$ $kg \cdot m^{-2}$ (indicating obesity), whereas the corresponding WC limit $>102$ cm identified 19.3% of our subjects as obese. Moreover, 19.0% of the HG subjects had a BIA estimated BF $\geq$25%, which is also classified as obesity (14). Because BF and WC are probably a more valid measure for obesity than BMI in military personnel (13), we conclude that about 2 of 10 HG soldiers/officers could be classified as obese.

Our studied HG subjects had 2.5% points lower BF and also lower BMI compared with the U.S. Arizona National Guard soldiers (35). However, our HG subjects had somewhat higher mean BMI, WC, %BF, and FFM compared with Finnish reservists (11,34), slightly higher SMM than Finnish conscripts (25), higher mean BMI compared with Norwegian infantry soldiers during basic training (9), and higher BMI and %BF compared with Norwegian Air Force cadets (1). It should be noted that our HG personnel on average were 3–13 years older than the soldiers in comparison.

The prevalence of obesity (BMI $>30$) in civilian Norwegian men, aged 30 years, has been reported from some large-scale studies as being around 15% in the year 2000–2003 (33), which is a slightly higher figure than in this study. Yet, more recent data on BMI and WC in civilian Norwegian men of same age showed slightly lower mean BMI and WC values compared with our HG soldiers (5,10). Thus, anthropometrical characteristics and prevalence of obesity is probably not very different between HG personnel and age-matched civilian counterparts.

The REG-HG soldiers achieved a mean estimated $\dot{V}O_2$peak at about 50 $ml \cdot kg^{-1} \cdot min^{-1}$, whereas the corresponding figure was $\sim$2 $ml \cdot kg^{-1} \cdot min^{-1}$ higher in the RAP-HG soldiers. However, this mean difference did not reach statistical significance after adjusting for differences in age, HG district, and military rank. This result was also somewhat surprising because the RAP-HG soldiers perform fitness tests prior to be accepted for the RAP force, like running 3,000 m in less than 15:00 minutes. Yet, this required 3,000 m performance will equal to a $\dot{V}O_2$max of $\sim$47 $ml \cdot kg^{-1} \cdot min^{-1}$ (6), which is also within reach for two thirds of the REG-HG soldiers. Accordingly, the rather low minimum requirement means less differentiation in aerobic fitness between the 2 HG forces. In addition, some HG districts have lacked volunteers for the RAP-HG force and consequently allowed soldiers to sign up, although fitness requirements were not always met (HG officers, personal communication).

Home Guard officers performed better on the 20-m SRT compared with HG private soldiers. Previous selection based on physical fitness could be an explanation for the difference seen between officers and private soldiers. Officers in the HG have at some time completed a Military Officer School, all of which have prerequisites for minimum fitness levels. The same fitness level is not expected from conscripts during compulsory military training. Thus, private soldiers in the HG have been less selected on physical fitness during their previous military career compared with the officers. This difference in fitness at young adulthood might track into later stages in life (24).

The physical demands for Norwegian HG soldiers, or similar reserve soldiers from other countries, are yet not well defined. However, our own data (Aandstad et al., unpublished results, 2009) indicate that REG-HG personnel performed more low-intensity activity, but less high-intensity activity, during military HG training compared with civilian life. If these data are representative for the aerobic demands in REG-HG force duty, then the majority of REG-HG personnel probably have a sufficient aerobic fitness level to perform their military tasks. We do not have adequate data to describe the physical demands related to RAP-HG military duty. Physical demands for a common military activity like loaded marching might also give us an idea of the physical capability of the HG personnel. The aerobic demands related to loaded marching are well established (28), and a minimum level of 43–50 $ml \cdot kg^{-1} \cdot min^{-1}$ has been recommended for the individual soldier to perform this activity adequately (27). The upper limit of 50 $ml \cdot kg^{-1} \cdot minute^{-1}$ has been recommended for special force soldiers (28) but should not be justified for the individual HG soldier and officer because their job tasks are usually less demanding. If we use the lower recommended level of 43 $ml \cdot kg^{-1} \cdot min^{-1}$ as an arbitrary minimum requirement for the REG-HG personnel, 87% of these subjects achieved this level. Similarly, if we define 47 $ml \cdot kg^{-1} \cdot min^{-1}$ (median of 43–50) as the required level for RAP-HG personnel, 82% of the RAP-HG soldiers attained this level.

Home Guard personnel perform some specific and well-defined job tasks, which could be quantified in relation to physical fitness requirements. Yet, they could also face unknown tasks and requirements like any other type of soldier and fight on the same battleground as full-time soldiers. Thus, it makes sense to evaluate HG soldiers' fitness level based on comparisons with other type of soldiers. The study by Warr et al. (35) is among the few that has studied aerobic capacity in reserve soldiers. Their study showed that the U.S. (Arizona) male National Guard soldiers had very similar $\dot{V}O_2$max values (directly measured) as our REG-HG personnel. However, their sample size was relatively low (53 men) and not necessarily a representative for the U.S. National Guard soldiers in general. Some large-scale studies have reported physical fitness levels in Finnish reservists (11,34). Finnish reserve soldiers and Norwegian HG soldiers have a relatively similar military background, with 6–12 months of previous compulsory military training before being enrolled as reserve soldiers. Although the studied Finnish reservists were younger, their mean $\dot{V}O_2$max was ~42 $ml \cdot kg^{-1} \cdot min^{-1}$, which is 16% lower compared with our HG personnel. Although a true difference in aerobic fitness might occur between Finnish reserve soldiers and Norwegian HG soldiers, we believe that at least some of the variance relates to dissimilar test modalities (cycle ergometer vs. 20-m SRT) and $\dot{V}O_2$max prediction equations.

Previous data on aerobic fitness in male Norwegian military personnel have found mean $\dot{V}O_2$max of 54–57 $ml \cdot kg^{-1} \cdot min^{-1}$ in infantry soldiers and Air Force cadets (1,8,9). Thus, our HG personnel had 7–12% lower aerobic capacity compared with previous studied soldiers in Norway. Compared with reference data on similar aged civilian Norwegian men, our HG personnel achieved 3–8% higher $\dot{V}O_2$peak (5,10). Thus, it seems that HG personnel have a slightly higher aerobic capacity compared with their civilian counterparts but somewhat lower values compared with younger full-time military personnel.

This study is the first to present data on anthropometrics, body composition, and aerobic fitness in Norwegian HG personnel. Data have been gathered from 10 test periods in 5 HG districts and included 799 soldiers and officers from 38 troops. Compliance with the study was high, especially if compared with studies on civilian populations. Hence, we think our data reflect the total HG population well, particularly the subgroup of REG-HG personnel. Because our RAP-HG personnel were recruited from 4 troops and 2 HG districts only, we are less sure if these data are representative for the total RAP-HG population.

To our best effort, we have used a random sampling procedure when selecting at HG district and troop level. However, optimal randomization was not always possible for logistical and practical reasons. For instance, some districts arranged HG training during similar weeks, leaving them with less chance of being selected for participation in the study. Moreover, some troops were unavailable for testing because they were temporarily occupied with out-of-garrison activities during our scheduled time for testing. However, we have no indication that our selection procedure has led to a biased sample.

The BIA method is an indirect method and considered less accurate than more intricate reference methods (3). Although an indirect method has limitations on the individual level, mean values and proportions could be well reflected if an appropriate prediction equation was chosen. We used the equation by Sun et al. (32) to estimate FFM and BF, and the equation by Janssen et al. (19) to estimate SMM. Both equations are based on a large multi-center validation studies, and with healthy subjects covering our soldiers' age range. Thus, we believe that the chosen equations produced fairly correct mean body composition values in our studied subjects.

We previously validated the 20-m SRT in a subsample of our HG soldiers (2), and the generated prediction equation has been used to estimate $\dot{V}O_2$peak in this study. Although this equation predicts $\dot{V}O_2$peak with some measurement error for the individual subject, the presented group $\dot{V}O_2$peak values should reflect directly measured values well.

Because we used an indirect aerobic fitness test, the traditional criteria for verifying maximal effort and the achievement of a true $\dot{V}O_2$max value were lacking (30); thus, the term $\dot{V}O_2$peak was used. However, the mean $HR_{peak}$ observed is in line with true maximal heart rate values (29). This indicates that effort was generally high and that the results reflect close to true maximal performance for the majority of subjects tested. In addition, the 110 subjects who refrained from participating in the 20-m SRT did not demonstrate significantly different anthropometrics or body composition compared with the participating subjects. Thus, we believe that the mean aerobic fitness values would not have changed much if all subjects had accepted to run the test.

Testing was performed under field conditions during military training, with less standardization regarding previous physical activity, nutrition, and sleep compared with an optimized laboratory setting. This might have reduced reliability of the BIA measurements and the performance in the running test (4,7). However, the HG military training did not seem to be very physically challenging, especially not for the REG-HG personnel, and sufficient sleep and nutrition are usually provided to the personnel. Thus, the majority of subjects were probably tested while in a normal physical condition.

## Practical Applications

This study has presented reference values for anthropometrics, body composition, and aerobic capacity in Norwegian HG personnel. The existing material helps Commanders and the General Inspector in understanding to which degree the 2 HG forces are capable of undertaking physically strenuous military work. It also gives the General Inspector a framework for deciding whether it is necessary to take action for increasing fitness levels within HG soldiers and officers. These data can also be used in the future to check for secular changes in fitness levels in Norwegian HG personnel. Finally, Commanders in other countries might compare their own reserve personnel against such a reference material, facilitating interpretation of their own fitness data.

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# PAPER IV

MILITARY MEDICINE, 181, 7:693, 2016

# Objectively Measured Physical Activity in Home Guard Soldiers During Military Service and Civilian Life

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**ABSTRACT** Soldiers are encouraged to be physically active, and thereby maintain or increase their fitness level to meet job-related physical demands. However, studies on objectively measured physical activity (PA) in soldiers are scarce, particular for reserve soldiers. Hence, the aim of this study was to present PA data on Norwegian Home Guard (HG) soldiers. A total of 411 HG soldiers produced acceptable PA measurements (SenseWear Armband $Pro_2$) during civilian life, of which 299 soldiers also produced acceptable data during HG military training. Reference data on total energy expenditure, metabolic equivalents, steps per day, and minutes of PA in three different metabolic equivalent categories are presented. The HG soldiers produced more minutes of moderate PA during HG military training compared to civilian life, but less vigorous and very vigorous PA. Furthermore, HG soldiers were more physically active during civilian week days compared to weekend days. The presented reference data can be used for comparisons against other groups of soldiers. Our data indicate that aerobic demands during HG military training were not very high. Promoting PA and exercise could still be important to ensure HG soldiers are physically prepared for more unforeseen job tasks.

## INTRODUCTION

Physical fitness and exercise training are emphasized in armed forces around the world since military service can be physically challenging.[1,2] Studies show that general exercise training can enhance military-related physical work capacity in soldiers,[3] while high levels of leisure time physical activity (PA) has been linked with more favorable aerobic fitness levels and body composition in officers.[4] Exercise training, PA, and fitness are also valued in the Norwegian Armed Forces, illustrated by regulations allowing all officers to exercise 2 hours per week during work hours and by the obligatory annual fitness tests for all officers and full-time soldiers. However, the focus on exercise and fitness has traditionally not applied to part-time reserve soldiers and officers within the Home Guard (HG).

The HG is the largest branch within the Norwegian Defense Forces in terms of number of personnel (45,000 soldiers and officers). The main function of the HG is to protect the local territory and population during warfare and civilian crisis. The HG consists of soldiers and officers selected from a pool of men (and a few women) who have completed their obligatory military service year or officer training. Service in the HG is mandatory for the selected men, whereas women volunteer. The selection criteria may vary among different HG districts. About 93% of HG soldiers belong to the Regular HG force, whereas the remaining 7% volunteer for a more comprehensive service in the Rapid Reaction HG force (the current study does not include Rapid Reaction HG force soldiers, but this force was described previously[5]). The Regular HG force soldiers are typically called for military training from 3 to 7 days per year. Thus, except for the few days of military training, HG soldiers live a civilian life. There are no fitness requirements to serve in the Regular HG force, and no military-organized exercise training exists for Regular HG soldiers. Thus, each individual is responsible for obtaining necessary “fitness for duty” during his or her civilian life.

Little attention to exercise and fitness within the HG may reflect anticipated low job-related physical demands. A main task for Regular HG soldiers is to protect important military and civilian objects (e.g., buildings, roads, bridges, and VIPs). Such stationary work is usually not very physically challenging. Yet, the HG also assists professional military forces, the police, or other civilian authorities during military crises, natural disasters, or rescue operations. The physical demands during this type of work may be higher. Until now, neither physical demands nor PA/fitness levels have been investigated in Norwegian HG soldiers. International studies in this field are also scarce. We have identified two previous studies evaluating physical demands in reserve soldiers; however, both investigated job tasks less relevant to our HG soldiers.[6,7] A few studies on fitness levels of reservists or National Guard soldiers and officers exist,[8–10] but these soldiers and officers are not always comparable to our HG personnel (e.g., recruited differently). Previous international studies on PA in reserve forces are also very limited, mainly presenting incomplete descriptions of self-reported PA.[9–11] Such PA questionnaires are often considered less valid than objective measurement techniques.[12] So far, objectively measured PA has primarily been reported on full-time soldiers in small-scale studies with other research aims than reporting population values of PA.[13–15] Accordingly, previous

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international literature has recommended increased research into health, physical fitness, and readiness of reservists.[8,16]

Based on the aforementioned research gaps, we initiated a study on PA and fitness levels in Norwegian HG soldiers. The fitness reference data were recently described in a separate article.[5] In this article, we present reference values on objectively measured PA levels in Regular HG force soldiers, describe how PA levels differed between civilian life and HG military training, and discuss whether HG soldiers' fitness level match the physical demands measured during HG training.

## METHODS

### Study Design and Ethics

This study is a descriptive cross-sectional study with a cluster-randomized sampling procedure. The study was approved by the Regional Committee for Medical and Health Research Ethics and the Norwegian Social Science Data Services. Subjects volunteered by giving their written consent after receiving written and oral information about the study.

### Subjects

The sampling procedure started by allocating all 13 HG districts into five groups, based on geographical location: North, South, East, West, and Mid-Norway. One HG district from each stratification group was randomly selected to participate in the study. Each of the five HG districts was visited twice between 2006 and 2009 during scheduled military HG training. Between two and six troops were randomly selected to participate at each visit. In total, Regular HG soldiers from 34 troops participated in the study.

All available soldiers and officers (*n* = 823) in the selected 34 troops received information about the study and were invited to participate. All prospective participants were men. Ninety-four subjects (11%) declined to participate (Fig. 1). Among the 729 soldiers who initially volunteered for the study, 61 later declined to wear the PA monitor. Since the number of volunteer subjects in some troops outnumbered the available monitors, 128 randomly selected soldiers were not offered monitors. Among the soldiers who received the monitor, data from 19 subjects (all from 1 troop) were later excluded because of a suspected inappropriate randomization. In addition, some monitors were not returned, and some data were lost because of technical errors. Ninety-four soldiers did not wear the monitor for a sufficient amount of time. Thus, 411 soldiers produced acceptable monitor data during civilian life, of which 299 subjects also produced acceptable data during HG military training. Among the 411 HG soldiers, 42 (10%) reported being reserve officers, whereas the rest were all private (compulsory enlisted) soldiers. We have analyzed officers and soldiers together and will use the term "HG soldiers" for the group combined.

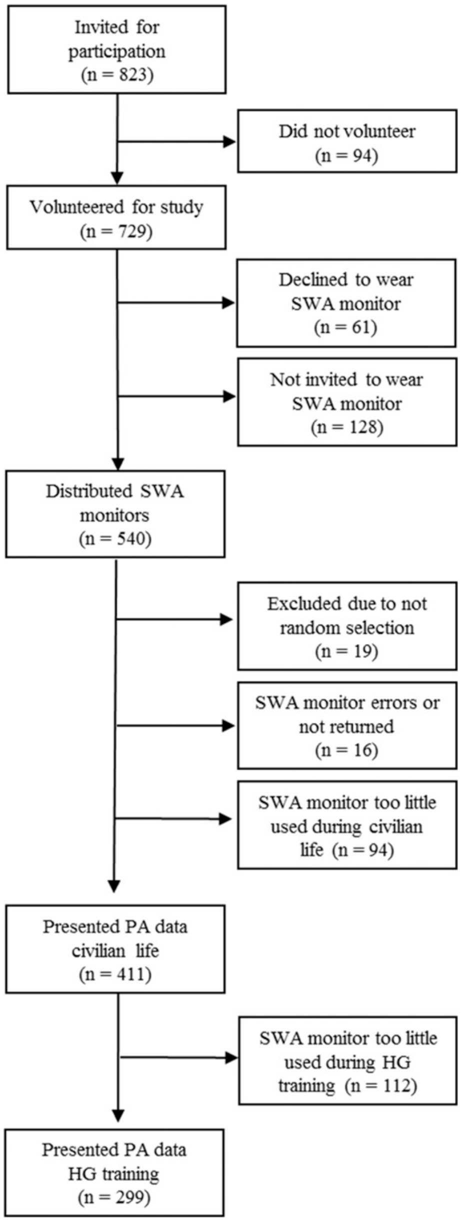


**FIGURE 1.** Flowchart of participation with included and missing physical activity monitor data.

Mean (SD) height, body mass, and body mass index were 180.5 (7.0) cm, 84.8 (13.1) kg, and 26.1 (3.7) kg·m$^{-2}$, respectively, among the 411 soldiers with accepted PA measurements. Mean age was 33 (5) years, with range from 21 to 44 years.

### Procedures

Body mass and height were measured using a calibrated combined digital scale and stadiometer (model 708; Seca, Hamburg, Germany) to the nearest 0.1 kg and 5 mm, respectively.

SenseWear Armband (SWA) $Pro_2$ monitors (BodyMedia, Pittsburgh, Pennsylvania) were used to measure PA. The SWA monitor measures heat flux, galvanic skin response, skin- and near-body temperature, and additionally includes a 2-axis accelerometer.[17] Validity of this monitor (including the software version we used) has previously been investigated in civilian and military adults.[18] The SWA monitor was distributed during HG training, immediately after physical testing was completed. The subjects were instructed to wear the monitor for all the remaining HG training days, and then for an additional 7 consecutive civilian days. Some subjects forgot to take the monitor off at the correct date and may have a few extra "wear days." These extra days have been included in the analysis. Some subjects were included in the study at the final day of their HG training; thus, no data on PA during military training was obtained in these subjects.

The subjects received thorough explanations (visual, oral, and written) on how to use the SWA monitor. The monitor was worn on the upper right arm at the triceps muscle and removed only during water activities. At the end of the measurement period, the monitor was returned by prepaid mail. The HG soldiers also returned a short questionnaire where they indicated the specific days they had worn the monitor during HG training and civilian life, respectively.

### Data Processing

The SWA data were collected at 1-minute intervals and downloaded using Innerview Professional Software v. 5.1 (BodyMedia). The software algorithms calculate values for several PA variables. We present data for the following six variables: total energy expenditure (TEE), number of steps, metabolic equivalents (METs),[19] and time in moderate (3–6 METs), vigorous (6–9 METs), and very vigorous (>9 METs) intensity PA.

A minimum of 20 hours of monitor wear time per day was treated as a valid day, whereas days with <20 hours of wear time were excluded from the analysis. Furthermore, inclusion criteria for an accepted civilian measurement period were at least 2 valid week days and 1 valid weekend day. Inclusion criteria for an accepted HG training measurement period were at least one valid HG training day (week day or weekend day) in addition to an accepted civilian measurement period. The day a soldier finished his HG training period and returned to civilian life was excluded from the analysis.

Data have been processed separately for civilian week days, civilian weekend days, and HG military training days. Mean values per day (for all six PA variables) were calculated from each subject's valid measurement days. We also calculated weighted mean values from civilian week days and civilian weekend days combined. For the weighted mean data, the 5 week days (Monday to Friday) contribute 5/7 to the generated weighted mean value, whereas the 2 weekend days (Saturday and Sunday) contribute 2/7.

### Statistical Analysis

All outcome variables, including their residuals, were checked for normality by visual inspections of data distribution plots. Normally distributed data are presented as mean with 95% confidence interval (CI) or SD, whereas skewed data are presented as median with 25th to 75th percentiles. Data on time in moderate, vigorous, and very vigorous intensity PA were skewed, in addition to including values of zero. Thus, square root transformations were performed before analyzing these data for differences between conditions. The data were subsequently back-transformed before being presented. We did not calculate CIs for differences for the back-transformed data, according to suggestions by Bland and Altman.[20] Differences in PA level between HG training and civilian life, and between civilian week days and weekend days, were analyzed with a linear mixed-effect model with restricted maximum likelihood approach and least significant difference CI adjustments. Thus, the mean difference values are based on estimated marginal means. Since data from the same individuals were compared over different time points, the data were analyzed as repeated measurements. The mixed model allowed us to account for the cluster randomized design, using troop as a random effect. The linear mixed-effect model was also used for the missing data analysis. Statistical analyses were performed in SPSS (version 21; IBM, Armonk, New York). A probability ($p$) of <0.05 was considered statistically significant.

## RESULTS

The mean (SD) number of days with accepted SWA wear time during civilian week days and weekend days was 4.3 (1.0) and 2.0 (0.6) days, respectively. The corresponding value during HG training was 1.4 (0.6) days. The mean (SD) wear time per day was 23:33 (00:25), 23:29 (00:39), and 23:45 (00:24) hours : minutes during the three mentioned time periods, respectively.

Civilian week days and weekend days PA data are presented separately in Table I. Among the HG soldiers with accepted SWA data during civilian life, the values for five out of six PA variables were significantly higher during week days compared to weekend days. The cumulative relative frequencies of the PA variables (for weighted mean of civilian week days and weekend days combined) are presented in Figure 2. The median time spent in ≥moderate intensity PA from the weighted mean of civilian week days and weekend days was approximately 3 hours (179 minutes) per day. This includes 4 minutes per day with very vigorous PA (>9 MET).

**TABLE I.** Physical Activity Characteristics During Civilian Week Days (Monday to Friday) and Weekend Days (Saturday and Sunday) in 411 Home Guard Soldiers

| Days of the Week | TEE (Kcal) | Steps (Number) | METs (Ratio Score) | Moderate PA (Minutes) | Vigorous PA (Minutes) | Very Vigorous PA (Minutes) |
|---|---|---|---|---|---|---|
| Week Days | 3,548 (3,472–3,623) | 10,448 (10,037–10,859) | 1.78 (1.74–1.82) | 153 (105–239) | 17 (8–33) | 3 (1–8) |
| Weekend Days | 3,382 (3,309–3,454) | 9,209 (8,780–9,638) | 1.70 (1.66–1.74) | 140 (93–209) | 15 (5–29) | 2 (0–7) |
| Difference (95% CI) | 166 (64–268) | 1,251 (628–1,874) | 0.08 (0.03–0.13) | 21 | 2 | 1 |
| *p* Value | 0.001 | <0.001 | 0.002 | 0.001 | 0.053 | 0.029 |

TEE, total energy expenditure; METs, metabolic equivalents; PA, physical activity; vig, vigorous. TEE, steps, and METs are presented as mean (95% CI) per day, whereas the other variables are presented as median (25th to 75th percentiles). Differences are based on estimated marginal means from the linear mixed-effect model and reflect week days minus weekend days. The 95% CI, with the CIs adjusted for the cluster sampling, are only given for TEE, steps, and METs.

Comparisons of PA characteristics between HG military training and civilian life (weighted mean of week days and weekend days combined) are shown in Figure 3. Data are based on the 299 soldiers who produced valid SWA data during both HG training and subsequent civilian life. The HG soldiers spent significantly more time in moderate intensity PA during HG training compared to civilian life, but less time in vigorous and very vigorous PA. There was no difference in mean TEE, steps, or METs between HG training days and civilian life days.

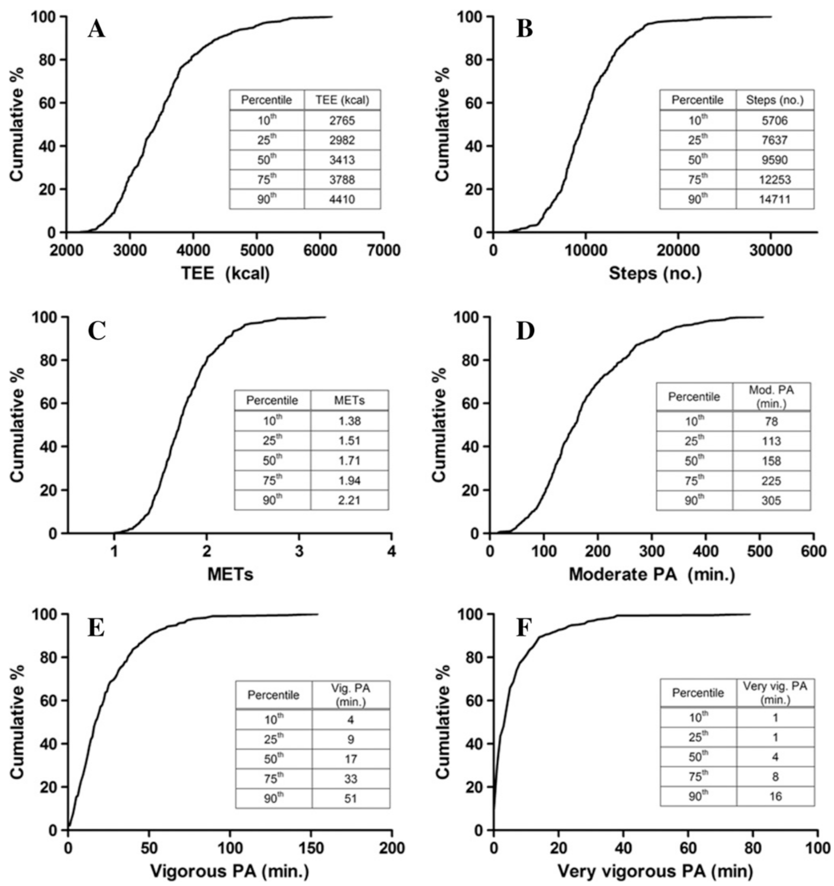


**FIGURE 2.** Cumulative relative frequency (%) for physical activity (PA) variables in 411 Home Guard (HG) soldiers during civilian life. The data represent weighted mean of week days and weekend days combined (average per day). (A) total energy expenditure (TEE), (B) total steps, (C) metabolic equivalents (METs), (D) time in moderate PA (3–6 METs), (E) time in vigorous PA (6–9 METs), and (F) time in very vigorous PA (>9 METs).

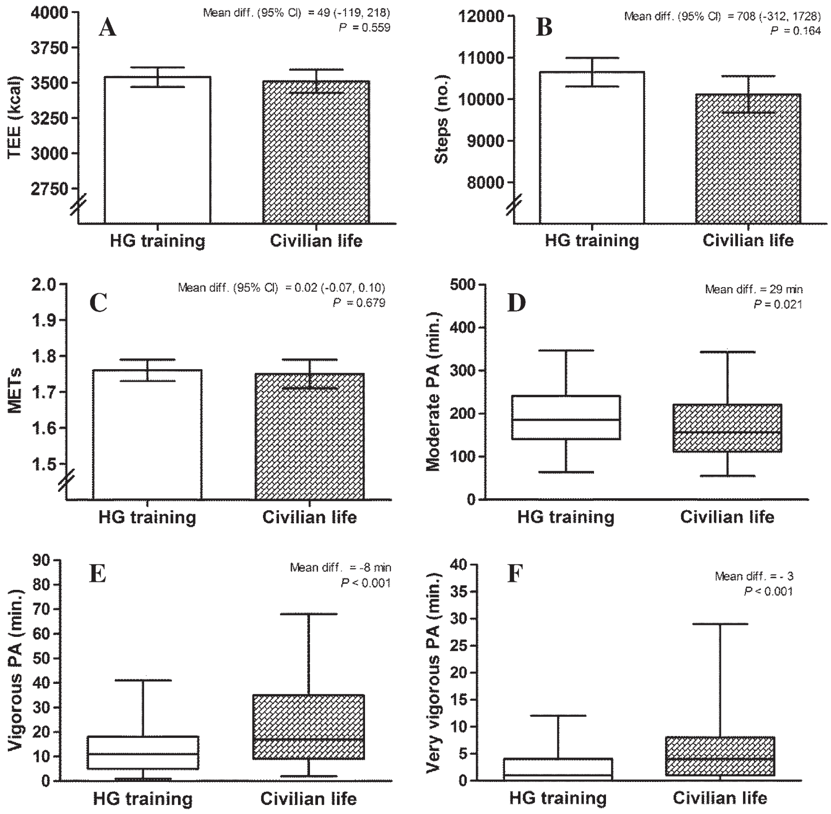


**FIGURE 3.** Comparison of physical activity (PA) characteristics in 299 Home Guard (HG) soldiers during HG military training and civilian life. The data represent weighted mean of week days and weekend days combined (average per day). Bars in (A) (total energy expenditure; TEE), (B) (steps) and (C) (metabolic equivalents; METs) represent mean (95% CI). In (D), (E), and (F) the boxes cover the range from 25th to 75th percentile, the whiskers cover the range from 5th to 95th percentile, while the horizontal line in the box indicate median. The text presents mean difference (included 95% CI for A, B, and C) between PA during HG training compared to civilian life, with corresponding *p* values.

Of the initial 729 HG soldiers who volunteered for the study, only 411 (56%) produced valid civilian SWA data. However, the 318 soldiers with missing civilian SWA data did not differ on age ($p$ = 0.180), height ($p$ = 0.422), body mass ($p$ = 0.784), or body mass index ($p$ = 0.589) from the 411 soldiers with valid civilian SWA data. The 112 soldiers with missing SWA data during HG training did not differ significantly on age, anthropometrics, or any SWA data gathered during civilian life, compared to the 299 soldiers with valid SWA data during both civilian life and HG training.

## DISCUSSION

The current study presents reference data on objectively measured PA in Norwegian HG soldiers during civilian life and HG military training. The data collected during civilian life display the general PA level of the subjects, whereas data collected during HG training indicate the aerobic-related physical demands during HG military service. In civilian studies, PA levels are often linked to health. In the present discussion we will rather focus on the link between PA, aerobic fitness, and military work demands.

### *PA During Civilian Life*

HG soldiers live a civilian life, except for the few days of HG training every year. Thus, the PA and exercise carried out during civilian life have a much larger impact on HG soldiers' fitness level compared to activity carried out during HG training. Consequently, the measured PA during civilian life might indicate whether the amount of exercise is sufficient to obtain (or maintain) necessary aerobic fitness for military work.

Our results demonstrate that HG soldiers are physically active approximately 3 hours per day (during civilian life) with an intensity of ≥3 METs. The majority of this time is spent in the "moderate" (3–6 METs) intensity zone. Since 1 MET is commonly set at 3.5 mL·kg$^{-1}$·min$^{-1}$ in oxygen consumption ($VO_2$),[21] it follows that this MET zone covers a $VO_2$ range from approximately 11 to 21 $mL \cdot kg^{-1} \cdot min^{-1}$. Our previously published data showed that the HG soldiers had an average estimated peak oxygen uptake ($VO_{2peak}$) of 50 $mL \cdot kg^{-1} \cdot min^{-1}$.[5] Consequently, the 3 to 6 MET zone corresponds to an intensity of approximately 21 to 42% of $VO_{2peak}$ for the average fit HG soldier. This exercise intensity does not seem to increase aerobic capacity in moderately trained individuals, or at least higher intensity exercise will be more effective.[22] The "vigorous" (6–9 METs) zone corresponds to an intensity of approximately 42 to 63% for the average fit HG soldier, whereas the "very vigorous" (>9 METs) zone corresponds to activity above 63% intensity. The latter zone probably yields the most effective aerobic exercise training in the studied HG soldiers. The soldiers produced 4 minutes PA (median value) per day in >9 METs, which corresponds to about half an hour per week. This may not seem like much, but is apparently sufficient to produce a mean $VO_{2peak}$ of 50 $mL \cdot kg^{-1} \cdot min^{-1}$ (probably considered a good aerobic fitness level for reserve soldiers[5]). Still, HG soldiers in general could benefit from more exercise with high intensity to maintain or increase their maximal aerobic capacity.

The studied HG soldiers were less physically active during civilian weekend days compared to week days. A large number of HG soldiers and officers reported their civilian work to have a substantial physical component (data not shown). This might be one reason why PA was higher during the week days. Higher PA levels during week days have also previously been reported in Norwegian children/adolescents and in U.S. adults.[23,24]

Our data can be compared to several studies on objectively measured PA in civilian adults.[25] Hansen et al[26] measured PA by accelerometers in >1,200 civilian Norwegian men aged from 20 to 64 years. They showed that 22% of the men achieved ≥10,000 steps per day, which is sometimes recommended as a minimum level related to health.[22] In comparison, 44% of our HG soldiers reached this cutoff value for steps during civilian life. In addition, Hansen et al reported a mean value of 37 minutes per day of PA ≥3 METs, which is remarkably lower than the approximately 3 hours per day found in this study. However, comparing PA values from different studies might be limited by several factors, such as the use of different PA monitors or different data processing methods.[21] We have identified some civilian studies which used the same monitor as in our study,[27–29] but comparisons to our data might still be difficult since different SWA software versions could produce different values.[30]

### PA During HG Training

Several previous studies have demonstrated high physical demands during military training,[13,31,32] and it is claimed that the physical demands placed on modern soldiers continue to be substantial.[1] However, our study found that PA level during HG training was not very different from the soldiers' PA level during civilian life. In fact, more high intensity PA was performed during civilian life compared to HG training, whereas the opposite was evident for moderate intensity PA. Thus, the aerobic fitness demands placed on Norwegian HG soldiers seems less than what is typically anticipated for soldiers in general.

Previous studies reporting PA levels in HG soldiers or reservists are scarce, with the exception of Talbot et al[33] who measured steps per day in male and female U.S. National Guard soldiers. Our HG soldiers walked more steps per day compared to the U.S. reserve soldiers. However, the groups are not directly comparable since the U.S. soldiers consisted of selected soldiers who all had failed the 2-mile run test, which might reflect lower PA level compared to the average U.S. National Guard soldier.

More PA data are available for nonreserve soldiers. Tharion et al[34] have presented several studies reporting TEE in various types of soldiers from around the world, all measured by doubly labeled water (DLW) during military field training and life in garrison. Mean TEE for the combined group of 424 male soldiers was 4,610 ± 650 kcal per day, which is approximately 30% higher than estimated TEE in our soldiers during HG training and civilian life. Finnish conscripts during basic training, U.S. Marine soldiers during a winter military training course, and Norwegian Army cadets during a 7-day field exercise also produced higher DLW–TEE values compared to our HG soldiers.[15,35,36] However, these measurements took place during strenuous military field training, which probably do not reflect PA levels during regular military life in garrison.

### Are HG Soldiers "Fit for Duty"?

Our previously published $VO_{2peak}$ values in HG soldiers indicated that members of this reserve force have a pretty good aerobic fitness level, particularly considering age and military training background.[5] Regular HG soldiers primarily carry out rather motionless work, with relatively low requirements for aerobic fitness. Yet, HG soldiers may also face unknown job tasks, for which they do not train during HG training. For example, HG soldiers are sometimes called out during mountain rescue operations or during natural disasters. Our PA measurements during HG training did not include this more unforeseen work, which may include higher physical requirements. Hence, we conclude that most HG soldiers have sufficient aerobic fitness for the preplanned tasks designated to the Regular HG force, although other less defined aspects of the work may be more restricted by the soldiers' physical capacity.

### Study Strengths and Limitations

This appears to be the first study of its scale on objectively measured PA in reserve soldiers. We objectively measured PA, which is generally considered more valid than self-reported methods.[12] We used a PA monitor that is validated in several studies, showing good agreement for estimated TEE against indirect calorimetry[18] and DLW.[37] The subjects produced a high monitor wear time, and data were gathered during both civilian life and HG training. A representative, geographically diverse sample was secured.

However, the study also had some limitations. Lack of compliance or missing data in different stages of the study might influence the results. About 50 to 95% (median 70%) of the soldiers met for the obligatory HG training in the five included districts, according to district officers. The remainder obtained permission to refrain from the annual training because of civilian work, travel, or sickness. According to the district officers these soldiers are probably missing at random, but we have no data to verify this. In addition, some soldiers declined to participate in the study and some did not produce valid measurements. We do not know whether these subjects differ in PA level compared to the subjects who volunteered, but the missing data analysis indicates that these data are missing at random.

This article only describes PA for Regular HG force soldiers. Ideally, PA data for Rapid Reaction HG soldiers would also have been presented. Four troops of Rapid Reaction HG soldiers were initially included in the study. For various reasons, only 12 soldiers produced accepted PA data during both civilian life and during HG training, which is too low to be presented as reference data.

The PA levels during civilian life were monitored the week after the HG annual training. It is possible that the HG training influenced the level of PA on the successive week (carryover effect). Soldiers who experienced physically hard work during the HG training might be less physically active the days after the HG training, and vice versa for personnel who experienced light work during the HG training. Moreover, PA level may be temporarily modified due to being monitored (Hawthorne effect). Yet, we do not have valid evidence for (or against) any modified behavior in the monitoring period. From international literature, the empirical evidence of modified behavior due to being monitored is equivocal and scarce.[38]

A thorough analysis of job-related physical demands should ideally include both a task and demand analysis.[39] The current study only included an analysis of the aerobic-related demands. HG training usually reflects the key tasks for this group; yet, the actual content of the HG training carried out during this study period was not recorded.

Although, it is claimed that the SWA monitor predicts TEE more accurately than the more frequently used waist-mounted accelerometers,[40] several other studies have shown that the SWA underestimates energy expenditure for high intensity activities.[18,41] Moreover, a previous validation study of the SWA showed that TEE and MET were underestimated during resistance training with external weight.[42] We did not register the HG soldiers' carried load during military training, but they always wore their combat uniform, and sometimes moved around with backpack, weapon, etc. This external load might lead to underestimated PA figures during HG training. Finally, it must also be emphasized that the SWA monitor is designed to measure aerobic-related PA only. Physical work that taxes other fitness components (like maximal strength) is not reflected in the SWA data.

## CONCLUSIONS

In the current study, we have described the PA level of Norwegian HG soldiers during military training and civilian life. The presented data can be used as reference values for PA in reserve soldiers and are particularly valuable as such data are scarce or nonexisting. In their civilian life, HG soldiers carried out moderate or higher intensity PA for approximately 3 hours per day. Yet, the majority of this PA was within the moderate range (3–6 METs), which is not effective aerobic exercise training. Our data also indicated that the aerobic demands were relatively low during HG training, and less vigorous and very vigorous PA were carried out during HG training compared to civilian life. Accordingly, taking previously published $VO_{2peak}$ data into account, most of the HG soldiers appeared to have a sufficient aerobic capacity to successfully carry out predefined tasks. We must, however, acknowledge that our study design does not give a complete picture of the physical demands placed on HG soldiers during military training and real-scenario work. Increased PA and exercise could therefore ensure HG soldiers are better physically prepared also for completing the less-frequent (but critical) job tasks. Thus, promoting PA and exercise among HG soldiers could still be valuable.

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**Pilot – Cadet Development Study:**

1) Letter from the Regional Committee for Medical and Health Research Ethics

2) Information letter to study participants

Appendix 1

**UNIVERSITETET I OSLO**
**DET MEDISINSKE FAKULTET**

1. amanuensis dr.scient. Reidar Säfvenbom
Norges idrettshøgskole
Pb. 4014 Ullevål Stadion
0806 Oslo

**Regional komité for medisinsk forskningsetikk**
**Sør- Norge (REK Sør)**
Postboks 1130 Blindern
NO-0318 Oslo

Telefon: 228 50 670
Telefaks: 228 44 661
E-post: juliannk@medisin.uio.no
Nettadresse: www.etikkom.no

**Dato:** 13.09.06
**Deres ref.:**
**Vår ref.: S-06317b**

S-06317b **Fysisk form, antropometri og fysisk aktivitet hos kadetter ved Luftkrigsskolen**

Komiteen behandlet søknaden i sitt møte onsdag 07.09.06.

Komiteen oppfatter prosjektene som kvalitetssikring av Luftkrigsskolens treningsopplegg for kadetter. Den omfattes derfor ikke av komiteens mandat om fremleggelsesplikt.

Komiteen anbefaler imidlertid at man opprettholder intensjonen om å innhente samtykke fra forsøkspersonene og at Datatilsynet søkes om godkjenning.

Med vennlig hilsen

Tor Norseth
Leder

Julianne Krohn-Hansen
Sekretær

Kopi til
Luftkrigsskolen i Trondheim v/Rune Nilsen, Persaunevei 61, 7046 Trondheim

NORGES IDRETTSHØGSKOLE

## Forespørsel om deltagelse i forskningsprosjektet "Fysisk form, antropometri og fysisk aktivitet hos kadetter ved Luftkrigsskolen"

Luftkrigsskolen ønsker i samarbeid med Norges idrettshøgskole Forsvarets institutt å kartlegge fysisk form, kroppssammensetning og fysisk aktivitet, samt registrere eventuelle endringer i disse parametrene gjennom studietiden, hos kadetter ved Luftkrigsskolen.

Datainnsamlingen i form av fysiske tester og måling av kroppssammensetning vil gjennomføres i uke 33/2006, deretter hver vår fram til avsluttet studie sommeren 2009. I tillegg inngår det i studien en kontinuerlig treningsregistrering gjennom alle de tre studieårene.

Studien består av følgende type datainnsamling:

1) Gjennomføre innendørs løpetest i gymsal (20 meter shuttle run test). Forsøkspersonene starter på linje, løper 20 meter til motsatt linje, og vender i henhold til innspilte lydsignaler. Løpshastigheten er lav i begynnelsen, men øker underveis i testen, og forsøkspersonen løper så lenge vedkommende klarer å følge lydsignalene (vanligvis 10-15 minutter). Testen krever at forsøkspersonene jobber opp mot maksimal innsats på slutten av testen. Ut fra tid løpt vil personens maksimale oksygenopptak kunne estimeres.

2) Direkte testing av maksimalt oksygenopptak. Forsøkspersonene løper på tredemølle, med neseklype og munnstykke for oppsamling av utåndingsluft. Løpshastigheten økes underveis i testen, inntil forsøkspersonen ikke orker å løpe mer. Hjertefrekvens og oksygenopptak måles underveis i testen. Tre minutter etter gjennomført test taes en bloddråpe fra fingertuppen for å analysere melkesyrekonsentrasjonen i blodet. Totalt med oppvarming tar testen ca 30 minutter. Før denne testen gjennomføres for første gang, vil forsøkspersonene trene på å løpe på tredemølle med munnstykke og neseklype, i en egen tilvenningstest.

3) Beregning av kroppssammensetning ved hjelp av bioimpedansmålinger. Forsøkspersonen ligger ned på en benk, og elektroder plasseres på henholdsvis høyre fot (vrist) og hånd. Ved hjelp av elektriske impulser (30 sekunders måleperiode) måles kroppens ledningsmotstand for beregning av fettprosent.

4) Måling/registrering av fysisk aktivitet ved hjelp av Armband aktivitetsmonitor og ved egenregistrering. Fysisk aktivitet vil måles over to 7-dagers perioder, ved hvert av studieårene ved Luftkrigsskolen. Monitoren festes rundt høyre overarm, og måler bevegelse og beregner energiomsetning og tiden man driver fysisk trening. Monitoren bør være festet på armen hele tiden i disse 7 dagene, unntatt ved dusjing/bading. Forsøkspersonene vil i tillegg få utdelt pulsklokke som benyttes ved all fysisk trening. Dataene som samles inn med pulsklokka utgjør grunnlaget for egenrapportering av all felles og individuell trening i løpet av de tre studieårene.

**Risiko ved deltagelse i studien**
Løpetestene krever at forsøkspersonen jobber opp mot sin maksimale kapasitet. Slike løpetester er ikke forbundet med spesiell risiko for friske og aktive mennesker. Forsøkspersoner med hjerteproblemer eller skader/sykdommer som hindrer maksimal fysisk innsats, bør derimot ikke gjennomføre løpetesten. Er du usikker på om du bør delta på løpetesten kan ansvarlig lege konsulteres. Ingen risiko ansees ved gjennomføring av de andre målingene.

**Fordeler ved deltagelse**
Studien vil blant annet gi deg objektive mål på din fysiske form sammenlignet med andre kadetter, samt mål på ditt gjennomsnittlige energiforbruk og fysisk aktivitetsnivå. Egne testresultater vil i etterkant av studien bli sendt ut til de som måtte ønske dette. Du vil også bli informert per post hvis dine verdier eller testresultater er av avvikende karakter.

**Anonymitet og etiske spørsmål**
Resultatene fra den enkelte forsøksperson vil behandles konfidensielt og anonymiseres i endelige publiseringer. Resultatene vil oppbevares på en slik at måte at forsøkspersonenes resultater kun vil knyttes opp mot en ID-kode og ikke den enkeltes navn eller personnummer. Du kan kreve å få dine innsamlede opplysninger og resultater slettet hvis ønskelig (men ikke dersom dataene allerede inngår i vitenskapelig arbeid/publikasjoner).

**Informert samtykke**

☐ Ja, jeg ønsker å delta i studien "Fysisk form, antropometri og fysisk aktivitet hos kadetter i Luftforsvaret". Jeg er klar over at jeg kan trekke meg fra hele eller deler av studien, når som helst, og uten begrunnelse.

Dato: ______________

Signatur: ______________________________________________

Mvh

Dr. Scient Reidar Säfvenbom
Prosjektleder NIH/F

Cand.Scient Anders Aandstad
Forsker NIH/F

Major Anders McD Sookermany
Forskningsleder NIH/F

Major Rune Nilsen
Studieleder Idrett, LKSK

**Body Composition Method Comparison Study:**

1) Letters from the Regional Committee for Medical and Health Research Ethics

2) Letter from the Norwegian Social Science Data Services

3) Information letters to study participants:

- Letter to Air Force Academy participants
- Letter to Ørland Main Air Station participants

Appendix 2

# UNIVERSITETET I OSLO

## DET MEDISINSKE FAKULTET

Stipendiat Anders Aandstad
Norges idrettshøgskole, Forsvarets institutt
Pb 4014 Ullevål Stadion
0806 Oslo

**Regional komité for medisinsk og helsefaglig forskningsetikk Sør-Øst D (REK Sør-Øst D)**
Postboks 1130 Blindern
NO-0318 Oslo

Telefon: 22 85 05 93
Telefaks: 22 85 05 90
E-post: i.m.middelthon@medisin.uio.no
Nettadresse:
http://helseforskning.etikkom.no/xnet/public

**Dato: 03.07.09**
**Deres ref.:**
**Vår ref.: 2009/169-1**

**Validering av måleinstrumenter for kroppssammensetning**
Komiteen behandlet søknaden 16.06.09. Prosjektet er vurdert etter lov om behandling av etikk og redelighet i forskning av 30. juni 2006, jfr. Kunnskapsdepartementets forskrift av 8. juni 2007 og retningslinjer av 27. juni 2007 for de regionale komiteer for medisinsk og helsefaglig forskningsetikk.

***Prosjekttema:***
*Antropometriske data i form av fettprosent benyttes til å bestemme en persons helsetilstand. I denne studien skal man validere tre metoder for dette; RJL Quantum II, InBody 720 og DXA for måling av kroppssammensetning. 60 personer, 30 av hvert kjønn, skal inkluderes i studien. Deltakerne er kadetter i forsvaret.*

**Forskningsetisk vurdering:**
Komiteen finner det nødvendig å påpeke at prosjektleder har et særlig ansvar for god veiledning av masterstudenter, noe som burde vært bedre ivaretatt i denne studien.

Prosjektdeltakerne er, som kadetter og vernepliktige, et ledd i et meget hierarkisk kommandosystem. Ved rekruttering av disse gruppene er varsomhet påkrevet i forhold til å ivareta frivillighet. Komiteen godtar av denne grunn ikke at overordnede i forsvaret har noen rolle i studien, og ber om at den designes slik at dette unngås.

I studien skal friske personer som ellers ikke vil bli utsatt for stråling utsettes for dette. Komiteen ber om en redegjørelse for stråledosen på dette grunnlaget.

I en av undersøkelsene i studien skal prosjektdeltakerne skannes i 10 minutter. Komiteen ber om en begrunnelse for dette og en redegjørelse for hvorfor dette anses som nødvendig.

**Komiteen har følgende merknader til informasjonsskrivet:**
Samtykkeerklæringen skal kun inneholde selve samtykket. Alt deltakeren samtykker til skal stå i informasjonsskrivet, noe som innebærer en omarbeiding av samtykkeerklæringen.

**Vedtak:**
**Vedtak utsettes. Det bes om tilbakemelding på merknaden som er anført, før endelig**

**vedtak kan fattes. Komiteens leder tar stilling til godkjenning av prosjektet etter mottatt svar.**

Vedtaket var enstemmig

REK har gått over til elektronisk saksbehandling og fått ny saksportal: http://helseforskning.etikkom.no. Vi ber om at svar på merknader og henvendelser til REK sendes inn via denne portalen eller på epost: post@helseforskning.etikkom.no. Vennligst oppgi REKs saksnummer.

Med vennlig hilsen

Stein A. Evensen (sign.)
Professor dr.med.
leder

Ingrid Middelthon (sign.)
komitésekretær

Kopi:

- Anders McD Sookermany, Forskningsleder, Norges idrettshøgskole, Forsvarets institutt
  anders.sookermany@nih.no

*Brevet er godkjent elektronisk*

**UNIVERSITETET I OSLO**
**DET MEDISINSKE FAKULTET**

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**Regional komité for medisinsk og helsefaglig forskningsetikk Sør-Øst D (REK Sør-Øst D)**
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E-post: i.m.middelthon@medisin.uio.no
Nettadresse:
http://helseforskning.etikkom.no/xnet/public

**Dato: 19.08.09**
**Deres ref.:**
**Vår ref.: 2009/169**

**Vedr. svar på merknader for studien ”Validering av måleinstrumenter for kroppssammensetning”**

Komiteen behandlet svar på merknader 19.08.09. Prosjektet er vurdert etter gjeldende regelverk med tilhørende forskrifter.

Komiteen finner svarene tilfredsstillende, men ønsker at informasjonsskjemaet ikke påskrives navnene til seksjonssjefen og
sjefen ved Luftkrigsskolen.

**Vedtak:**
**Prosjektet godkjennes under forutsetning av at merknaden som er anført ovenfor blir innarbeidet før prosjektet settes i gang.**

Komiteenes vedtak kan påklages til Den nasjonale forskningsetiske komité for medisin og helsefag. Klagen skal sendes REK Sør-Øst D. Klagefristen er tre uker fra den dagen du mottar dette brevet.

REK har gått over til elektronisk saksbehandling og fått ny saksportal: http://helseforskning.etikkom.no. Vi ber om at svar på merknader og henvendelser til REK sendes inn via denne portalen eller på epost: post@helseforskning.etikkom.no. Vennligst oppgi REKs saksnummer.

Med vennlig hilsen

Stein A. Evensen (sign.)
Professor dr.med.
leder

Ingrid Middelthon (sign.)
komitésekretær

Kopi:
Anders McD Sookermany, Forskningsleder, Norges idrettshøgskole, Forsvarets institutt
anders.sookermany@nih.no

*Brevet er godkjent elektronisk*

**Norsk samfunnsvitenskapelig datatjeneste AS**
NORWEGIAN SOCIAL SCIENCE DATA SERVICES

Harald Hårfagres gate 29
N-5007 Bergen
Norway
Tel: +47-55 58 21 17
Fax: +47-55 58 96 50
nsd@nsd.uib.no
www.nsd.uib.no
Org.nr. 985 321 884

Anders Aandstad
Forsvarets institutt
Norges idrettshøgskole
Postboks 4014 Ullevål stadion
0806 OSLO

Vår dato: 24.07.2009 Vår ref: 22272 / 2 / AH Deres dato: Deres ref:

## TILRÅDING AV BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 01.07.2009. Meldingen gjelder prosjektet:

| | |
|---|---|
| *22272* | *Validering av tre metoder for kroppssammensetningsanalyser: Inbody 720, RJL-system og kalipermåling Harpenden mot DXA-måling* |
| *Behandlingsansvarlig* | *Norges idrettshøgskole, ved institusjonens øverste leder* |
| *Daglig ansvarlig* | *Anders Aandstad* |
| *Student* | *Kristian Holtberget* |

Personvernombudet har vurdert prosjektet, og finner at behandlingen av personopplysninger vil være regulert av § 7-27 i personopplysningsforskriften. Personvernombudet tilrår at prosjektet gjennomføres.

Personvernombudets tilråding forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, eventuelle kommentarer samt personopplysningsloven/-helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvern/forsk stud/skjema.html. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://www.nsd.uib.no/personvern/prosjektoversikt.jsp.

Personvernombudet vil ved prosjektets avslutning, 31.12.2014, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

for
Bjørn Henrichsen

Åsne Halskau

Kontaktperson: Åsne Halskau tlf: 55 58 89 26
Vedlegg: Prosjektvurdering
Kopi: Kristian Holtberget, Damvegen 6A, 1923 SØRUM

Luftforsvaret
Luftkrigsskolen

NORGES IDRETTSHØGSKOLE

## Forespørsel om deltagelse i studien:

## ”Validering av fire metoder for kroppssammensetningsanalyser: Inbody 720, RJL-system og kalipermålingen Harpenden mot DXA-måling”

**Innledning**
Norges idrettshøgskole Forsvarets institutt har for tiden et samarbeid med de tre Krigsskolene om å gjennomføre ”Kadettutviklingsstudien 07-11”. Studien har som mål å blant annet kartlegge utvikling i fysisk form, fysisk aktivitet og kroppssammensetning gjennom tre års krigsskolestudier. Kadetter i 2. og 3. avdeling ved Luftkrigsskolen deltar i denne studien.

**Studiens mål**
Vi ønsker nå å kvalitetssikre deler av datainnsamlingen i Kadettutviklingsstudien med et nytt delprosjekt med formål å undersøke nøyaktigheten på målemetoden for beregning av kroppssammensetning (fettprosent). Tre ulike metoder for beregning av fettprosent vil sammenlignes mot en kjent metode som betegnes som ”gullstandard”.

**Utvalg**
Alle 1. årskadetter ved Luftkrigsskolen (kull 60), samt alle jenter (vernepliktige og befal) ved Ørland Flystasjon, vil inviteres til å delta i studien. Totalt er det ønskelig at om lag 30 menn og 30 kvinner deltar i studien.

**Metoder**
Alle målinger gjennomføres om morgenen eller formiddagen. Møt fastende (siste måltid minimum 10 timer før måling), samt unngå meget hard fysisk aktivitet siste døgn før måling. Unngå røyking/snusing siste to timer før test. Du kan drikke vann som normalt før måling finner sted.

Det er planlagt at hver forsøksperson stiller til testing tre ganger i løpet av tre dager. Totalt vil det benyttes om lag 4 timer på å få gjennomført alle målingene.

Studien innebærer følgende datainnsamling:

1) Hudfoldsmåling. Tykkelsen på hudfold måles fire steder på kroppen. Det gjennomføres tre målinger på hvert sted. Målingen vil gjennomføres to ganger på forskjellige dager.

2) Bioimpedans – RJL. Forsøkspersonen ligger ned på en matte, og elektroder plasseres på henholdsvis høyre fot og hånd. Ved hjelp av elektriske impulser (10 sekunders måleperiode) måles kroppens ledningsmotstand for beregning av fettprosent. Målingen vil gjennomføres to ganger på forskjellige dager.

3) Bioimpedans – InBody 720. Forsøkspersonene står på maskinens gulvplate og holder i håndtakene med fast grep og tommel på angivelig sted. Forsøkspersonen står i ro uten å snakke under hele testen. Testtiden er ca 2 minutter. Målingen vil gjennomføres to ganger på forskjellige dager.

4) DXA. Forsøkspersonen legger seg ned på ryggen på en benk. Målingen gjennomføres ved at forsøkspersonen scannes mens vedkommende ligger i ro på benken. Måletiden er om lag 3:30 minutter. Målingen vil gjennomføres en gang i løpet av prosjektet (12 personer vil gjennomføre målingen to ganger)

**Risiko ved deltagelse**
DXA-målingene innebærer helkroppsscanning. DXA-maskinen benytter røntgenstråler, men i forhold til regulære røntgenbilder er stråledosen fra DXA beskjeden, og utgjør således ingen eller minimal helserisiko. Stråledosen ved DXA tilsvarer tre dagers normal stråling ved opphold på jordoverflaten. Ingen risiko ansees ved gjennomføring av bioimpedansmåling eller hudfoldsmåling.

**Fordeler ved deltagelse**
Studien vil blant annet gi deg objektive mål på din kroppssammensetning sammenlignet med andre kadetter, vernepliktige og normalbefolkningen. Egne testresultater vil bli tilgjengelig i etterkant av studien for de som måtte ønske dette. Du vil få mulighet til å snakke med fagpersonell tilknyttet studien for personlig tilbakemelding rundt spørsmål du måtte ha vedrørende dine egne målinger.

**Anonymitet og etiske spørsmål**
Det er frivillig å delta i studien. Du har anledning til å unnlate å delta på enkelte av testene og du har full rett til å trekke deg fra undersøkelsen når som helst, uten å måtte oppgi årsaken til dette. Dette vil ikke få konsekvenser for deg i din videre tjeneste i Forsvaret. Du kan kreve å få slettet dine innsamlede data hvis ønskelig (gjelder ikke dersom dataene allerede inngår i vitenskapelig publikasjoner). Målingene tatt på deg og informasjonen som registreres om deg skal kun brukes slik som beskrevet i hensikten med studien. Det er kun prosjektleder på Forsvarets Institutt ved Norges idrettshøgskole som vil ha tilgang på personidentifiserbare data (koblingsnøkkel), og vedkommende har taushetsplikt. Personidentifiserbare data kan ikke spores av personell på Krigsskolene eller på Ørland og alle data vil anonymiseres i utrapporteringen. Data fra studien vil ikke benyttes i kommersiell sammenheng. Prosjektet vil sluttføres 31.12.2014 ved at datamaterialet da vil anonymiseres. Studien er innmeldt til Norsk Samfunnsvitenskaplig Datatjeneste og Regional komité for medisinsk forskningsetikk.

**Informert samtykke**
Studien krever samtykke fra potensielle forsøkspersoner og vi ber deg derfor om å fylle ut slippen på neste siden hvis du ønsker å delta i studien. Eventuelle spørsmål om studien kan rettes til prosjektleder Anders Aandstad (se kontaktinformasjon under)

Dersom du ønsker å delta i studien undertegner du samtykkeerklæringen på siste side. Dersom du senere ønsker å trekke deg tar du kontakt med prosjektleder Aandstad ved Norges idrettshøgskole Forsvarets institutt (ansvarlig institusjon).

Med vennlig hilsen

Anders Aandstad
Prosjektleder valideringsstudie
Norges idrettshøgskole Forsvarets Institutt
Pb. 4014 Ullevål Stadion
0806 Oslo
E-post: anders.aandstad@nih.no
Tlf: 23 26 21 18/950 73 842

| | | |
|---|---|---|
| Anders Aandstad | Anders McD Sookermany | Kristian Holtberget |
| Prosjektleder NIH/F | Seksjonssjef NIH/F | Masterstudent NIH |

Luftforsvaret
Luftkrigsskolen

NORGES IDRETTSHØGSKOLE

**Samtykke til deltagelse i studien "Validering av fire metoder for kroppssammensetningsanalyser"**

Jeg er villig til å delta i studien

---------------------------------------------------------------------------------------------------------

(Signatur, dato)

## Forespørsel om deltagelse i studien:

## ”Validering av fire metoder for kroppssammensetningsanalyser: Inbody 720, RJL-system og kalipermålingen Harpenden mot DXA-måling”

**Innledning**
Norges idrettshøgskole Forsvarets institutt har for tiden et samarbeid med de tre Krigsskolene om å gjennomføre ”Kadettutviklingsstudien 07-11”. Studien har som mål å blant annet kartlegge utvikling i fysisk form, fysisk aktivitet og kroppssammensetning gjennom tre års krigsskolestudier.

**Studiens mål**
Vi ønsker nå å kvalitetssikre deler av datainnsamlingen i Kadettutviklingsstudien med et nytt delprosjekt med formål å undersøke nøyaktigheten på målemetoden for beregning av kropps-sammensetning (fettprosent). Tre ulike metoder for beregning av fettprosent vil sammenlignes mot en kjent metode som betegnes som ”gullstandard”.

**Utvalg**
Alle 1. årskadetter ved Luftkrigsskolen, samt alle jenter (vernepliktige og befal under 40 år) ved Ørland Flystasjon, vil inviteres til å delta i studien. Totalt er det ønskelig at om lag 30 menn og 30 kvinner deltar i studien.

**Metoder**
Alle målinger gjennomføres om morgenen eller formiddagen. Forsøkspersonene skal møte fastende (siste måltid minimum 10 timer før måling), samt unngå meget hard fysisk aktivitet siste døgn før måling. Unngå røyking/snusing siste to timer før test. Du kan drikke vann som normalt før måling finner sted.

Det er planlagt at hver forsøksperson stiller til testing tre ganger i løpet av tre dager. En av målingene vil gjennomføres i Trondheim og dette vil ta om lag 8 timer. De to andre testdagene gjennomføres på Ørland og vil ta om lag 20 minutter hver gang.
Studien innebærer følgende datainnsamling:

1) Hudfoldsmåling. Tykkelsen på hudfold måles fem steder på kroppen. Det gjennomføres tre målinger på hvert sted. Målingen vil gjennomføres to ganger på forskjellige dager.

2) Bioimpedans – RJL. Forsøkspersonen ligger ned på en matte, og elektroder plasseres på henholdsvis høyre fot og hånd. Ved hjelp av elektriske impulser (10 sekunders måleperiode) måles kroppens ledningsmotstand for beregning av fettprosent. Målingen vil gjennomføres to ganger på forskjellige dager.

3) Bioimpedans – InBody 720. Forsøkspersonene står på maskinens gulvplate og holder i håndtakene med fast grep og tommel på angivelig sted. Forsøkspersonen står i ro uten å snakke under hele testen. Testtiden er ca 2 minutter. Målingen vil gjennomføres to ganger på forskjellige dager.

4) DXA. Forsøkspersonen legger seg ned på ryggen på en benk. Målingen gjennomføres ved at forsøkspersonen scannes mens vedkommende ligger i ro på benken. Måletiden er om lag 3:30 minutter. Målingen vil gjennomføres en gang i løpet av prosjektet.

**Risiko ved deltagelse**

DXA-målingene innebærer helkroppsscanning. DXA-maskinen benytter røntgenstråler, men i forhold til regulære røntgenbilder er stråledosen fra DXA beskjeden, og utgjør således ingen eller minimal helserisiko. Stråledosen ved DXA tilsvarer tre dagers normal stråling ved opphold på jordoverflaten. Ingen risiko ansees ved gjennomføring av bioimpedansmåling eller hudfoldsmåling.

**Fordeler ved deltagelse**

Studien vil blant annet gi deg objektive mål på din kroppssammensetning sammenlignet med andre kadetter, vernepliktige og normalbefolkningen. Egne testresultater vil bli tilgjengelig i etterkant av studien for de som måtte ønske dette. Du vil få mulighet til å snakke med fagpersonell tilknyttet studien for personlig tilbakemelding rundt spørsmål du måtte ha vedrørende dine egne målinger.

**Anonymitet og etiske spørsmål**

Det er frivillig å delta i studien. Du har anledning til å unnlate å delta på enkelte av testene og du har full rett til å trekke deg fra undersøkelsen når som helst, uten å måtte oppgi årsaken til dette. Dette vil ikke få konsekvenser for deg i din videre tjeneste i Forsvaret. Du kan kreve å få slettet dine innsamlede data hvis ønskelig (gjelder ikke dersom dataene allerede inngår i vitenskapelig publikasjoner). Målingene tatt på deg og informasjonen som registreres om deg skal kun brukes slik som beskrevet i hensikten med studien. Det er kun prosjektleder på Forsvarets Institutt ved Norges idrettshøgskole som vil ha tilgang på personidentifiserbare data (koblingsnøkkel), og vedkommende har taushetsplikt. Personidentifiserbare data kan ikke spores av personell på Krigsskolene eller på Ørland og alle data vil anonymiseres i utrapporteringen. Data fra studien vil ikke benyttes i kommersiell sammenheng. Prosjektet vil sluttføres 31.12.2014 ved at datamaterialet da vil anonymiseres. Studien er innmeldt til Norsk Samfunnsvitenskaplig Datatjeneste og Regional komité for medisinsk forskningsetikk.

**Informert samtykke**

Studien krever samtykke fra potensielle forsøkspersoner og vi ber deg derfor om å fylle ut slippen på neste siden hvis du ønsker å delta i studien. Eventuelle spørsmål om studien kan rettes til prosjektleder Anders Aandstad (se kontaktinformasjon under)

Dersom du ønsker å delta i studien undertegner du samtykkeerklæringen på siste side. Dersom du senere ønsker å trekke deg tar du kontakt med prosjektleder Aandstad ved Norges idrettshøgskole Forsvarets institutt (ansvarlig institusjon).

Med vennlig hilsen

Anders Aandstad
Prosjektleder valideringsstudie
Norges idrettshøgskole Forsvarets Institutt
Pb. 4014 Ullevål Stadion
0806 Oslo
E-post: anders.aandstad@nih.no
Tlf: 23 26 21 18/950 73 842

| Anders Aandstad | Anders McD Sookermany | Kristian Holtberget |
|---|---|---|
| Prosjektleder NIH/F | Seksjonssjef NIH/F | Masterstudent NIH |

**Samtykke til deltagelse i studien ”Validering av fire metoder for kroppssammensetningsanalyser”**

Jeg er villig til å delta i studien

-----------------------------------------------------------------------------------------------------------------
(Signatur, dato)

**Moving Home Guard soldiers Study:**

1) Letters from the Regional Committee for Medical and Health Research Ethics

2) Letter from the Norwegian Social Science Data Services

3) Information letters to study participants:

- Letter to participants in the main descriptive study
- Letter to participants in the main descriptive study, including the 20 m SRT method comparison study
- Letter to participants in the main descriptive study, including blood samples for cardiovascular disease risk study

4) Information letter (including questionnaire) related to the physical activity monitor

5) Questionnaire (truncated)

Appendix 3

UNIVERSITETET I OSLO
DET MEDISINSKE FAKULTET

1. amanuensis dr.scient. Reidar Säfvenbom
Norges idrettshøgskole
Pb. 4014 Ullevål Stadion
0806 Oslo

**Regional komité for medisinsk forskningsetikk**
**Sør- Norge (REK Sør)**
Postboks 1130 Blindern
NO-0318 Oslo

Telefon: 228 44 666
Telefaks: 228 44 661
E-post: rek-2@medisin.uio.no
Nettadresse: www.etikkom.no

**Dato:** 28.04.06
**Deres ref.:**
**Vår ref.:** S-06164

S-06164 **Hele HV i bevegelse - kartleggingsundersøkelse**

Komiteen har følgende merknader til prosjektsøknaden:
Til delstudie 1:

1. Komiteen oppfatter søknaden slik at deltagelse i spørreundersøkelsen skal være frivillig, men at det gjennomføres slik at den kan etterspores hvem som svarer og hvem som ikke svarer, jf utlovet mulighet for premiering. Komiteen finner ikke dette forenlig med at deltagelse skal være frivillig. Komiteen legger til grunn at frivillighet best ivaretas ved at de som ønsker å svare, gjør det anonymt.
2. Komiteen finner at det fremlagte spørreskjema inneholder spørsmål som ikke synes relevante for å kartlegge fysisk aktivitet, motivasjon eller iver til slik aktivitet.
3. Kvinner er utelukket i prosjektet, jf punkt 7 i søknaden. Det skal sterke grunner til for å fravike hovedregelen om at begge kjønn skal inkluderes. Komiteen finner allikevel i dette tilfelle å kunne akseptere dette, jf den begrunnelse som er gitt.

Til delstudie 2:

1. Komiteen finner ikke at rekrutteringsmåten, med pliktig fremmøte, er forenlig med at det er lagt til grunn frivillig deltagelse. Det samme gjelder at den enkelte skriftlig skal måtte bekrefte at deltagelse ikke ønskes. De som ikke ønsker å delta, skal ikke trenge å bekrefte dette skriftlig.
2. Det bør opprettes et system for oppfølging av patologiske funn.
3. Komiteen oppfatter studien slik at det skal tas blod- og vevsprøver til forskningsformål. I så fall må det søkes om opprettelse av en forskningsbiobank. Sosial- og helsedirektoratet informeres deretter om komiteens standpunkt av REK ved at komiteens vedtak (etter behandling av den innsendte biobanksøknaden fra prosjektleder) oversendes sammen med søknaden om opprettelse av forskningsbiobank.

Komiteen har følgende merknader til informasjonsskrivene:

1. "Forespørsel om deltagelse i forskningsprosjekt (og evt. prosjektets tittel)" bør være hovedoverskriften på informasjonsskrivene.
2. Informasjonsskrivene bør generelt holdes i en nøytral for. Formuleringer som f. eks. "kjære utvalgte HV-soldat" og "vi er svært takknemlige " skal utgå.
3. "Anonymisert" må erstattes med "avidentifisert", da kodenøkkel beholdes.
4. Feltet "Jeg ønsker ikke å delta i prosjektet" går ut, da pasienter som ikke ønsker å delta i prosjektet, ikke skal ha plikt til å informere om dette (vedlegg 6)
5. Regional komité for medisinsk forskningsetikk, Sør-Norge godkjenner ikke, men tilrår studier.

<u>Vedtak:</u>
Komiteen finner ikke å kunne tilrå prosjektet slik det er presentert i søknaden. Komiteen ber om at det vurderes om prosjektet kan gjennomføres på en måte som ivaretar reell frivillighet og anonymitet hos deltagere i delprosjekt 1 og frivillighet uten pliktig fremmøte for å stilles overfor spørsmål om eventuell

deltagelse. Det forutsettes videre at spørreskjemaet vurderes i forhold til hvorvidt alle spørsmål er nødvendige å ha med i forhold til prosjektets oppgitte formål. I tillegg må det søkes om opprettelse av forskningsbiobank, og det forutsettes at informasjonsskriv justeres. Komiteen vil evt. ta stilling til prosjektet på nytt, dersom svar på merknadene og reviderte informasjonsskriv innsendes.

Med vennlig hilsen

Kristian Hagestad
Fylkeslege cand.med., spes. i samf.med
Fungerende leder

Jørgen Hardang
Rådgiver
Sekretær

**UNIVERSITETET I OSLO**
**DET MEDISINSKE FAKULTET**

1. amanuensis dr.scient. Reidar Säfvenbom
Norges idrettshøgskole
Pb. 4014 Ullevål Stadion
0806 Oslo

**Regional komité for medisinsk forskningsetikk**
**Sør- Norge (REK Sør)**
Postboks 1130 Blindern
NO-0318 Oslo

Telefon: 228 44 666
Telefaks: 228 44 661
E-post: rek-2@medisin.uio.no
Nettadresse: www.etikkom.no

**Dato:** 6.6.06
**Deres ref.:**
**Vår ref.:** S-06164

S-06164 **Hele HV i bevegelse - kartleggingsundersøkelse**

Vi viser til brev datert 24.5.06 vedlagt revidert informasjonsskriv og samtykkeerklæring

Komiteen har ingen merknader til revidert informasjonsskriv og samtykkeerklæring.

Komiteen tilrår at prosjektet gjennomføres.

Vi ønsker lykke til med prosjektet.

Med vennlig hilsen

Kristian Hagestad
Fylkeslege cand.med., spes. i samf.med
Fungerende leder

Jørgen Hardang
Sekretær

UNIVERSITETET I OSLO
DET MEDISINSKE FAKULTET

1. amanuensis dr.scient. Reidar Säfvenbom
Norges idrettshøgskole
Pb. 4014 Ullevål Stadion
0806 Oslo

**Regional komité for medisinsk forskningsetikk**
**Sør- Norge (REK Sør)**
Postboks 1130 Blindern
NO-0318 Oslo

Telefon: 228 44 666
Telefaks: 228 44 661
E-post: rek-2@medisin.uio.no
Nettadresse: www.etikkom.no

**Dato:** 22.6.06
**Deres ref.:**
**Vår ref.:** S-06164

S-06164 **Hele HV i bevegelse - kartleggingsundersøkelse**

Vi viser til brev datert 1.6.06 vedlagt revidert informasjonsskriv med samtykkeerklæring, informasjon om spørreundersøkelse og kopi av søknad om opprettelse av forskningsbiobank datert 1.6.06.

Komiteen tar svar på merknader til etterretning.

Komiteen har ingen merknader til skjema for opprettelse av forskningsbiobank.

Komiteen har ingen merknader til revidert informasjonsskriv og samtykkeerklæring.

Komiteen tilrår at prosjektet gjennomføres og at forskningsbiobank opprettes.

Komiteen videresender skjema for opprettelse av forskningsbiobank og informasjonsskrivet samt komiteens vedtak til Sosial- og helsedirektoratet for endelig behandling av opprettelse av forskningsbiobanken.

Vi ønsker lykke til med prosjektet.

Med vennlig hilsen

Kristian Hagestad
Fylkeslege cand.med., spes. i samf.med
Fungerende leder

Jørgen Hardang
Sekretær

Kopi: Sosial- og helsedirektoratet, Postboks 7000, St. Olavs plass, 0130 Oslo

**Norsk samfunnsvitenskapelig datatjeneste AS**
NORWEGIAN SOCIAL SCIENCE DATA SERVICES

NSD

Harald Hårfagres gate 29
N-5007 Bergen
Norway
Tel: +47-55 58 21 17
Fax: +47-55 58 96 50
nsd@nsd.uib.no
www.nsd.uib.no
Org.nr. 985 321 884

Reidar Säfvenbom
Forsvarets institutt
Norges idrettshøgskole
Postboks 4014 Ullevål stadion
0806 OSLO

Vår dato: 11.05.2006 Vår ref: 14655/SS Deres dato: Deres ref:

## TILRÅDING AV BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 31.03.2006. Meldingen gjelder prosjektet:

| | |
|---|---|
| *14655* | *Hele HV i bevegelse. En kartleggingsstudie* |
| *Behandlingsansvarlig* | *Norges idrettshøgskole, ved institusjonens øverste leder* |
| *Daglig ansvarlig* | *Reidar Säfvenbom* |

Personvernombudet har vurdert prosjektet, og finner at behandlingen av personopplysninger vil være regulert av § 7-27 i personopplysningsforskriften. Personvernombudet tilrår at prosjektet gjennomføres.

Personvernombudets tilråding forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldingen, korrespondanse med ombudet, eventuelle kommentarer samt personopplysningsloven/-helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvern/endringsskjema. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://www.nsd.uib.no/personvern/register/

Personvernombudet vil ved prosjektets avslutning, 01.01.1900 rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Bjørn Henrichsen Synnøve Serigstad

Kontaktperson: Synnøve Serigstad tlf: 55 58 35 42

Vedlegg: Prosjektvurdering

NORGES IDRETTSHØGSKOLE

# Forespørsel om deltagelse i forskningsprosjektet "HV i bevegelse"

Generalinspektøren for HV (GIHV) har besluttet å gjennomføre en større studie av HV-personell i Norge, i samarbeid med Forsvarets Institutt ved Norges idrettshøgskole. Studien er forankret i GIHVs behov for dokumentasjon av blant annet personellets fysiske aktivitet og fysiske form.

Du er en av 750 HV-soldater som er tilfeldig trukket ut og har mulighet til å delta i denne studien.

Datainnsamlingen vil primært gjennomføres i løpet av HV-øvelsen du nå tar del i. Nærmere informasjon om tidspunktet for datainnsamlingen får du fra prosjektleder.

Studien består av følgende punkter:

1) Besvaring av spørreskjema om blant annet fysisk aktivitetsvaner og motivasjon til fysisk aktivitet

2) Gjennomføre en innendørs løpetest i gymsal (20 meter shuttle run test). Forsøkspersonene starter på linje, løper 20 meter til motsatt linje, og vender i henhold til innspilte lydsignaler. Løpshastigheten er meget lav i begynnelsen, men øker underveis i testen, og forsøkspersonen løper så lenge vedkommende klarer å følge lydsignalene (vanligvis ca 6-15 minutter). Testen krever at forsøkspersonene jobber opp mot maksimal innsats på slutten av testen. Ut fra tid løpt vil personens maksimale oksygenopptak (kondisjon) kunne beregnes

3) Måle kroppssammensetning ved hjelp av såkalt bioimpedans måling. Forsøkspersonen ligger ned på gulvet, iført treningsklær, men uten sokker og sko. To elektroder plasseres på hånd og fot, og en svak elektrisk impuls sendes gjennom kroppen. Ut fra målingen kan prosentvis andel muskler, fett og vann beregnes.

4) Antropometriske målinger, det vil si måling av vekt, høyde og omkrets mage/hofte

5) Måling av fysisk aktivitet ved hjelp av Armband monitor. Fysisk aktivitet vil måles over en 10-dagers periode ved hjelp av en aktivitetsmonitor. Monitoren festes rundt høyre overarm, og måler din bevegelse og beregner energiomsetning og tiden man er fysisk aktiv. Monitoren bør være festet på armen hele tiden i disse 10 dagene, men skal taes av ved dusjing/bading. Monitoren er lett og liten og føles komfortabel å ha på armen. Monitoren settes på armen under HV-øvelsen, samt at du bærer den en ukes tid etter HV-øvelsen. Etter 10 dager sender du monitoren i ferdig frankert konvolutt tilbake til Norges idrettshøgskole

**Norges idrettshøgskole**
The Norwegian University
of Sport and Physical Education

**Postadresse:**
P. O. BOX 4014 - Ullevål Stadion
NO-0806 Oslo

**Besøksadresse:**
Sognsv. 220
www.nih.no

Telefon: (+47) 23 26 20 00
Org.nr.: NO 971526033
postmottak@nih.no

Risiko ved deltagelse i studien
Løpetesten krever at forsøkspersonen jobber opp mot sin maksimale kapasitet. En slik løpetest er ikke forbundet med spesiell risiko for friske og aktive mennesker. Forsøkspersoner med hjerteproblemer eller skader/sykdommer som hindrer maksimal fysisk innsats, bør derimot ikke gjennomføre løpetesten. Er du usikker på om du bør delta på løpetesten kan prosjektansvarlig konsulteres. Ingen risiko ansees ved gjennomføring av de andre målingene.

Fordeler ved deltagelse
Studien vil blant annet gi deg objektive mål på din fysiske form sammenlignet med andre HV-soldater, samt ditt gjennomsnittlige energiforbruk og fysisk aktivitetsnivå. Egne testresultater vil i etterkant av studien bli sendt ut til de som måtte ønske dette, så snart resultatene er ferdig bearbeidet. Du vil også bli informert per post hvis dine verdier eller testresultater er av avvikende karakter.

Anonymitet og etiske spørsmål
Resultatene fra den enkelte forsøksperson vil behandles konfidensielt og anonymiseres i endelige publiseringer. Resultatene vil oppbevares på en slik at måte at forsøkspersonenes resultater kun vil knyttes opp mot en ID-kode og ikke den enkeltes navn eller personnummer. Du kan kreve å få dine innsamlede opplysninger og resultater slettet hvis ønskelig (gjelder ikke dersom dataene allerede inngår i vitenskapelig arbeid/publikasjoner). Studien gjennomføres for øvrig med konsesjon fra Datatilsynet, med godkjenning fra Biobankregisteret og er tilrådt av etisk komité for medisinsk forskning.

Informert samtykke

(Hvis du ikke ønsker å delta i studien skal du ikke krysse av under eller signere)

☐ Ja, jeg ønsker å delta i studien "HV i bevegelse – kartleggingsundersøkelse". Jeg er klar over at jeg kan trekke meg fra hele eller deler av studien, når som helst, og uten begrunnelse.

Dato: ________________

Signatur (skriv tydelig): ________________________________________________

Mvh

Dr. Scient Reidar Säfvenbom
Prosjektleder NIH/F

Cand.Scient Anders Aandstad
Forsker NIH/F

Major Anders McD Sookermany
Forskningsleder NIH/F

# Forespørsel om deltagelse i forskningsprosjektet "HV i bevegelse"

Generalinspektøren for HV (GIHV) har besluttet å gjennomføre en større studie av HV-personell i Norge, i samarbeid med Forsvarets Institutt ved Norges idrettshøgskole. Studien er forankret i GIHVs behov for dokumentasjon av blant annet personellets fysiske aktivitet og fysiske form.

Datainnsamlingen vil gjennomføres i løpet av HV-øvelsen du nå tar del i, samt et oppmøte i uke 11 eller 12. Nærmere informasjon om tidspunktet for datainnsamlingen får du fra prosjektleder.

Studien består av følgende punkter:

1) Besvaring av spørreskjema om blant annet fysisk aktivitetsvaner og motivasjon til fysisk aktivitet

2) Gjennomføre innendørs løpetest i gymsal (20 meter shuttle run test). Forsøkspersonene starter på linje, løper 20 meter til motsatt linje, og vender i henhold til innspilte lydsignaler. Løpshastigheten er meget lav i begynnelsen, men øker underveis i testen, og forsøkspersonen løper så lenge vedkommende klarer å følge lydsignalene (vanligvis ca 6-15 minutter). Testen krever at forsøkspersonene jobber opp mot maksimal innsats på slutten av testen. Ut fra tid løpt vil personens maksimale oksygenopptak (kondisjon) kunne beregnes. Testen gjennomføres to ganger, med to dagers mellomrom.

3) Måle kroppssammensetning ved hjelp av såkalt bioimpedans måling. Forsøkspersonen ligger ned på gulvet, iført treningsklær, men uten sokker og sko. To elektroder plasseres på hånd og fot, og en svak elektrisk impuls sendes gjennom kroppen. Ut fra målingen kan prosentvis andel muskler, fett og vann beregnes. Testen gjennomføres to ganger, med to dagers mellomrom.

4) Antropometriske målinger, det vil si måling av vekt, høyde, omkrets mage/hofte og hudfoldstykkelse

5) Gjennomføre tilvenningstest for løping på tredemølle. Forsøkspersonen varmer opp ved løp på tredemølle i cirka 10 minutter. Deretter løper forsøkspersonen samme type testprotokoll som ved en reell VO2maks-test, men gir seg cirka 2 minutter før utmattelse. Ingen målinger gjennomføres eller registreres.

6) Gjennomføre test av maksimalt oksygenopptak. Forsøkspersonen varmer opp ved gang og løp på tredemølle i cirka 15 minutter. Stigningsgraden på tredemøllen settes til 5,3%, forsøkspersonen påsettes munnstykke for oppsamling av utåndingsluft, og begynner å løpe (evnt gå) på en individuelt tilpasset hastighet. Hvert minutt økes hastigheten med 1 km/t, og forsøkspersonen løper til utmattelse. Testens varighet er vanligvis på mellom 4 og 7 minutter. Oksygenopptak, hjertefrekvens og tid løpt registreres. Test av melkesyre taes 3 minutter etter endt test.

**Risiko ved deltagelse i studien**
Løpetestene krever at forsøkspersonen jobber opp mot sin maksimale kapasitet. Slike løpetester er ikke forbundet med spesiell risiko for friske og aktive mennesker. Forsøkspersoner med hjerteproblemer eller skader/sykdommer som hindrer maksimal fysisk innsats, bør derimot ikke gjennomføre løpetestene. Er du usikker på om du bør delta på løpetesten kan prosjektansvarlig konsulteres. Ingen risiko ansees ved gjennomføring av de andre målingene.

**Fordeler ved deltagelse**
Studien vil blant annet gi deg objektive mål på din fysiske form og kroppssammensetning sammenlignet med andre HV-soldater. Egne testresultater vil i etterkant av studien bli sendt ut til de som måtte ønske dette, så snart resultatene er ferdig bearbeidet.

**Anonymitet og etiske spørsmål**
Resultatene fra den enkelte forsøksperson vil behandles konfidensielt og anonymiseres i endelige publiseringer. Resultatene vil oppbevares på en slik at måte at forsøkspersonenes resultater kun vil knyttes opp mot en ID-kode og ikke den enkeltes navn eller personnummer. Du kan kreve å få dine innsamlede opplysninger og resultater slettet hvis ønskelig (gjelder ikke dersom dataene allerede inngår i vitenskapelig arbeid/publikasjoner). Studien gjennomføres for øvrig med konsesjon fra Datatilsynet, med godkjenning fra Biobankregisteret og er tilrådt av etisk komité for medisinsk forskning.

**Informert samtykke**

(Hvis du ikke ønsker å delta i studien skal du ikke krysse av under eller signere)

☐ Ja, jeg ønsker å delta i studien "HV i bevegelse – kartleggingsundersøkelse". Jeg er klar over at jeg kan trekke meg fra hele eller deler av studien, når som helst, og uten begrunnelse.

Dato: _________________

Signatur: ____________________________________________________

Mvh

Dr. Scient Reidar Säfvenbom
Prosjektleder NIH/F

Cand.Scient Anders Aandstad
Forsker NIH/F

Major Anders McD Sookermany
Forskningsleder NIH/F

NORGES IDRETTSHØGSKOLE

## Forespørsel om deltagelse i forskningsprosjektet "HV i bevegelse"

Generalinspektøren for HV (GIHV) har besluttet å gjennomføre en større studie av HV-personell i Norge, i samarbeid med Forsvarets Institutt ved Norges idrettshøgskole. Studien er forankret i GIHVs behov for dokumentasjon av blant annet personellets fysiske aktivitet og fysiske form.

Du er en av 750 HV-soldater som er tilfeldig trukket ut og har mulighet til å delta i denne studien.

Datainnsamlingen vil primært gjennomføres i løpet av HV-øvelsen du nå tar del i. Nærmere informasjon om tidspunktet for datainnsamlingen får du fra prosjektleder.

Studien består av følgende punkter:

1) Besvaring av spørreskjema om blant annet fysisk aktivitetsvaner og motivasjon til fysisk aktivitet

2) Gjennomføre en innendørs løpetest i gymsal (20 meter shuttle run test). Forsøkspersonene starter på linje, løper 20 meter til motsatt linje, og vender i henhold til innspilte lydsignaler. Løpshastigheten er meget lav i begynnelsen, men øker underveis i testen, og forsøkspersonen løper så lenge vedkommende klarer å følge lydsignalene (vanligvis ca 6-15 minutter). Testen krever at forsøkspersonene jobber opp mot maksimal innsats på slutten av testen. Ut fra tid løpt vil personens maksimale oksygenopptak (kondisjon) kunne beregnes

3) Måle kroppssammensetning ved hjelp av såkalt bioimpedans måling. Forsøkspersonen ligger ned på gulvet, iført treningsklær, men uten sokker og sko. To elektroder plasseres på hånd og fot, og en svak elektrisk impuls sendes gjennom kroppen. Ut fra målingen kan prosentvis andel muskler, fett og vann beregnes.

4) Antropometriske målinger, det vil si måling av vekt, høyde og omkrets mage/hofte

5) Måling av fysisk aktivitet ved hjelp av Armband monitor. Fysisk aktivitet vil måles over en 10-dagers periode ved hjelp av en aktivitetsmonitor. Monitoren festes rundt høyre overarm, og måler din bevegelse og beregner energiomsetning og tiden man er fysisk aktiv. Monitoren bør være festet på armen hele tiden i disse 10 dagene, men skal taes av ved dusjing/bading. Monitoren er lett og liten og føles komfortabel å ha på armen. Monitoren settes på armen under HV-øvelsen, samt at du bærer den en ukes tid etter HV-øvelsen. Etter 10 dager sender du monitoren i ferdig frankert konvolutt tilbake til Norges idrettshøgskole

6) Blodprøvetaking for måling av bl.a. kolesterol, triglyserider, insulin og glukose

**Norges idrettshøgskole**
The Norwegian University
of Sport and Physical Education

**Postadresse:**
P. O. BOX 4014 - Ullevål Stadion
NO-0806 Oslo

**Besøksadresse:**
Sognsv. 220
www.nih.no

Telefon: (+47) 23 26 20 00
Org.nr.: NO 971526033
postmottak@nih.no

Risiko ved deltagelse i studien
Løpetesten krever at forsøkspersonen jobber opp mot sin maksimale kapasitet. En slik løpetest er ikke forbundet med spesiell risiko for friske og aktive mennesker. Forsøkspersoner med hjerteproblemer eller skader/sykdommer som hindrer maksimal fysisk innsats, bør derimot ikke gjennomføre løpetesten. Er du usikker på om du bør delta på løpetesten kan prosjektansvarlig konsulteres. Ingen risiko ansees ved gjennomføring av de andre målingene.

Fordeler ved deltagelse
Studien vil blant annet gi deg objektive mål på din fysiske form sammenlignet med andre HV-soldater, samt ditt gjennomsnittlige energiforbruk og fysisk aktivitetsnivå. Egne testresultater vil i etterkant av studien bli sendt ut til de som måtte ønske dette (gjelder ikke resultatene fra blodprøvene), så snart resultatene er ferdig bearbeidet. Du vil også bli informert per post hvis dine verdier eller testresultater er av avvikende karakter.

Anonymitet og etiske spørsmål
Resultatene fra den enkelte forsøksperson vil behandles konfidensielt og anonymiseres i endelige publiseringer. Resultatene vil oppbevares på en slik at måte at forsøkspersonenes resultater kun vil knyttes opp mot en ID-kode og ikke den enkeltes navn eller personnummer. Du kan kreve å få dine innsamlede opplysninger og resultater slettet hvis ønskelig (gjelder ikke dersom dataene allerede inngår i vitenskapelig arbeid/publikasjoner). Studien gjennomføres for øvrig med konsesjon fra Datatilsynet, med godkjenning fra Biobankregisteret og er tilrådt av etisk komité for medisinsk forskning.

Informert samtykke

(Hvis du ikke ønsker å delta i studien skal du ikke krysse av under eller signere)

☐ Ja, jeg ønsker å delta i studien "HV i bevegelse – kartleggingsundersøkelse". Jeg er klar over at jeg kan trekke meg fra hele eller deler av studien, når som helst, og uten begrunnelse.

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# Informasjon om aktivitetsmonitoren Armband

| | |
|---|---|
| ID-nr (person) | |
| Armband-nr | |

## Bruk

- Monitoren skal alltid sitte på høyre overarm (se bildet)
- Monitoren skal taes av ved dusjing og bading, men ellers være påmontert hele tiden, også når du sover
- Ikke stram båndet for hardt, det skal ikke være ubehagelig stramt
- Det er lett at monitoren sklir ned når du f.eks tar av genseren. I så fall flytter du monitoren tilbake i riktig posisjon på armen
- Du trenger ikke trykke på noe for å starte monitoren, den starter av seg selv når du setter den på armen (og slutter å måle når du tar den av)
- Når du setter monitoren på armen vil du som regel etter en stund høre en summelyd og vibrering – dette er normalt. Tilsvarende hører man vanligvis et lydsignal når du tar av monitoren. Innimellom kan monitoren også avgi lyd/vibrasjon mens du har den på armen. Dette er også normalt.
- Ikke trykk på knappen på monitoren eller ta opp lokket
- Ikke lån bort monitoren til andre, det er kun du som skal benytte monitoren
- Ved spørsmål rundt bruken av armband, ta kontakt per mail: anders.aandstad@nih.no

## Tidsrom for din måling

| | | |
|---|---|---|
| Start måling (klokkeslett/dato): | | |
| Avslutt måling (klokkeslett/dato): | | |

## Innsendingsrutiner

Send inn monitoren umiddelbart etter at måleperioden er ferdig (dvs senest dagen etter avluttet måleperiode). NB! DETTE ER MEGET VIKTIG DA MONITOREN SKAL BENYTTES I ANDRE HV-OMRÅDER RETT ETTERPÅ.

Legg monitoren i vedlagt frankert svarkonvolutt. Svar på spørsmålene på baksiden på dette arket, og legg det sammen med monitoren i konvolutten, og send med posten. Konvolutten er ferdig frankert og påført mottaksadresse.

## Vennligst besvar følgende spørsmål

**1. Har monitoren vært behagelig å gå med?** (ett kryss)

☐ Svært behagelig ☐ Ganske behagelig ☐ Noe ubehagelig ☐ Svært ubehagelig

Hvis monitoren har vært svært eller noe ubehagelig å gå med – hva skyldes dette?

________________________________________________________________________________

**2. Har du hatt monitoren på armen stort sett hele tiden i disse 10 dagene?** (ett kryss)

☐ Nei, jeg har hatt monitoren på armen i liten eller ingen grad

☐ Det er en eller flere dager, eller lengre perioder, jeg ikke har hatt monitoren på armen

☐ Jeg har stort sett hatt monitoren på armen, men tatt den av ved enkelte anledninger/kortere perioder

☐ Jeg har hatt monitoren på armen tilnærmet hele tiden, unntatt ved dusjing/bading

Hvis du i lange perioder ikke har hatt monitoren på armen – hva skyldes dette?

________________________________________________________________________________

**3. Hvor fysisk aktiv har du vært i perioden du har hatt på monitoren, sammenlignet med normalt?**

☐ Mye mer fysisk aktiv enn vanlig

☐ Litt mer fysisk aktiv enn vanlig

☐ Like fysisk aktiv som vanlig

☐ Litt mindre fysisk aktiv enn vanlig

☐ Mye mindre fysisk aktiv enn vanlig

**4. Når reiste du hjem fra den siste HV-øvelsen?** Dag/dato:______________ Klokkeslett (ca): ___________

**5. Er du høyre- eller venstrehendt?** ☐ Høyrehendt ☐ Venstrehendt

**Ønsker du å få tilsendt dine resultater fra de fysiske testene/målingene, samt data fra målingen av din fysiske aktivitet (monitor-data)?** ☐ Nei ☐ Ja

Hvis ja: fyll ut under og vi vil sende deg resultatene dine per e-post eller vanlig post innen ca en måned

| | |
|---|---|
| Navn | |
| Adresse | |
| Poststed og postnummer | |
| E-post adresse | |
| Telefon | |

**VI TAKKER FOR DIN DELTAGELSE OG INNSATS I PROSJEKTET "HELE HV I BEVEGELSE"!**

ID-nr:

**Spørreundersøkelse i forbindelse med prosjektet "Hele HV i bevegelse"**

Generalinspektøren for HV (GIHV) har besluttet å gjennomføre en større studie av HV-personell i Norge. Studien er forankret i GIHVs behov for dokumentasjon av personellets varierende fysiske form samt deres varierende interesse av, og mulighet for å ivareta personlig fysisk helse/yteevne. GIHV ønsker å anvende studien i forbindelse med eventuelle aktivitetstilbud overfor HV-personell i fremtiden.

Forsvarets Institutt ved Norges idrettshøgskole skal gjennomføre studien som blant annet består av en spørreundersøkelse. Du er en av dem som er trukket ut til å delta i denne spørreundersøkelsen og vi er svært takknemlig for ditt svar.

Studien gjennomføres på konsesjon fra Datatilsynet og er godkjent av etisk komité for forskning. Det er frivillig å delta i studien og det er mulig å unnlate å svare på enkeltspørsmål. Dersom studien skal kunne gi et riktig bilde av HV-personellet er det imidlertid viktig at vi får oppriktige svar fra alle. Besvarelsene kan ikke spores av annet militært personell, dataene vil bli behandlet konfidensielt og anonymisert i utrapporteringen.

Lykke til med utfyllingen!

**Seksjon 1: I denne seksjonen spør vi deg om forhold som påvirker din hverdagssituasjon. Vi spør om utdannelse, hva du bruker tiden din på og hvordan du opplever Heimevernet. Til slutt spør vi noen spørsmål om dine nærmeste venner og hvordan du forholder deg til det moderne i forhold til det som er velkjent**

**1) Kjønn:** ☐ Mann
☐ Kvinne

**2) Alder:** ☐☐ år
**3) Høyde:** ☐☐☐ cm
**4) Vekt:** ☐☐☐ kg

**5) Sivil stand:** (ett kryss)
☐ Gift / partnerskap
☐ Samboer
☐ Enslig med kjæreste
☐ Enslig uten kjæreste

**6) Antall barn (under 18 år ) i husstanden din**

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gutt(er) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Jente(r) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**7) Alder på yngste barn**
☐☐ år

**8) Hvor mye tid bruker du på frivillig arbeid i idrettslag, korps, menighet etc. i løpet av en gjennomsnittsuke?** (ett kryss)
☐ Ingen tid
☐ 1-2 timer
☐ 3-4 timer
☐ 5 timer eller mer

**9) Hvor mye tid bruker du på å pleie/hjelpe egne foreldre/svigerforeldre i en gjennomsnittsuke?** (ett kryss)
☐ Ingen tid
☐ 1-2 timer
☐ 3-4 timer
☐ 5 timer eller mer

**10) Innbyggere i bostedskommune,** (ett kryss):
☐ Under 1000
☐ 1000 - 5000
☐ 5000 – 10.000
☐ 10.000 – 20.000
☐ 20.000 – 30.000
☐ mer enn 30.000

**11) Din høyeste utdannelse**
(Ett kryss for høyeste gjennomførte skolegang)

- ☐ Grunnskole
- ☐ Videregående allmennfag
- ☐ Videregående yrkesfag
- ☐ Sivil høgskole / universitet 1-3 år
- ☐ Sivil høgskole / universitet 3-6 år
- ☐ Sivil høgskole / universitet 7 år eller mer

**12) I hvor stor grad er ditt sivile yrke stillesittende?** ☐☐☐ %

**13) Hva er din stillingsprosent i ditt sivile yrke?** ☐☐☐ %

**14) Hvor mye overtid jobber du pr måned?** ☐☐☐ timer

**15) Hva stemte du ved siste stortingsvalg?** ………………………

**16) Hva er din inntekt pr år?** (ett kryss)

- ☐ Mindre enn 200.000
- ☐ 200.000 – 400.000
- ☐ 400.000 – 600.000
- ☐ 600.000 – 800.000
- ☐ 800.000 – 1 million
- ☐ Mer enn 1 million

**17) Har du tilgang på internett hjemme?** (ett kryss)

- ☐ Ja
- ☐ Nei
- ☐ Vet ikke

**18) Hvor ofte leser du riksaviser som Dagbladet, Aftenposten, VG, Dagens Næringsliv etc (også via internett)?** (ett kryss)

- ☐ Hver dag
- ☐ En gang i blant
- ☐ Aldri

**19) Har du en hobby du bruker mer enn fem timer på pr uke?**

- ☐ Ja
- ☐ Nei

**20) Hvis ja på 19, skriv inn hva hobbyen går ut på:**

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**21) Når leste du sist en hel bok?** (ett kryss)

- ☐ Flere år siden
- ☐ Ca ett år siden
- ☐ Ca 6 mnd siden
- ☐ Jeg leser en bok nå
- ☐ Jeg leser bøker hele tiden

**22) Hvilken type bok leste du sist?** (ett kryss)

- ☐ Krim
- ☐ Fagbok
- ☐ Roman
- ☐ Biografi
- ☐ Historisk bok

**23) Har du egen sykkel?** (ett kryss)

- ☐ Vet ikke
- ☐ Ja, men bruker den ikke
- ☐ Ja, men bruker den sjelden
- ☐ Ja, og jeg bruker den regelmessig (flere ganger pr uke om sommeren)
- ☐ Nei, jeg har ikke egen sykkel

**24) Har du fjelltelt?** (ett kryss)

- ☐ Vet ikke
- ☐ Ja, men bruker det ikke
- ☐ Ja, men bruker det sjeldent
- ☐ Ja, og jeg bruker det hvert år
- ☐ Nei, jeg har ikke eget fjelltelt

**25) Har du egen fiskestang?** (ett kryss)

- ☐ Vet ikke
- ☐ Ja, men bruker den ikke
- ☐ Ja, men bruker den sjelden
- ☐ Ja, og jeg bruker den regelmessig (flere ganger om sommeren)
- ☐ Nei, jeg har ikke egen fiskestang

**26) Har du private joggesko?** (ett kryss)

- ☐ Vet ikke
- ☐ Ja, men bruker dem ikke til trening
- ☐ Ja, men bruker dem sjelden til trening
- ☐ Ja, og jeg bruker dem regelmessig til trening
- ☐ Nei, jeg har ikke joggesko

**27) Hva er din oppfatning om HV?** (ett kryss)

- ☐ HV er en etterlevning fra fortiden uten funksjon
- ☐ HV er tross alle forsøk på modernisering en akterutseilt militær enhet
- ☐ HV ser ut til å kunne bli en militær enhet med en viss verdi
- ☐ HV er i ferd med å bli en relativt velorganisert del av Forsvaret
- ☐ HV er i ferd med å bli en velorganisert og kraftfull del av Forsvaret

**28) Hvordan opplever du HV-øvelsene?** (ett kryss)

- ☐ HV-øvelsene er totalt meningsløse og totalt uten innhold eller verdi
- ☐ HV-øvelsene er gjennomgående slappe og innholdsløse uten stor verdi
- ☐ HV-øvelsene er noen ganger godt organisert med bra innhold
- ☐ HV-øvelsene er rimelig meningsfulle med tanke HVs rolle i Forsvaret
- ☐ HV-øvelsene er svært meningsfulle med svært verdifullt innhold

**29) Hvor er du plassert i HV?** (ett kryss)

- ☐ Innsatsstyrke
- ☐ Forsterkningsstyrke
- ☐ Oppfølgingsstyrke
- ☐ Ikke tilknyttet en spesiell styrke
- ☐ Vet ikke

**30) Hvor lenge har du vært i HV?** (ett kryss)

- ☐ Ett år eller mindre
- ☐ 2 – 3 år
- ☐ 4 – 6 år
- ☐ 7 år eller mer

**31) Hva er din funksjon i HV?** (ett kryss)

- ☐ Befal og ansatt i Forsvaret
- ☐ Befal i HV, men ikke ansatt i Forsvaret
- ☐ Menig (vanlig HV-soldat)
- ☐ Vet ikke

**32) Hvilket HV-område tilhører du?**

- ☐ Vet ikke
- ☐ HV-01
- ☐ HV-02
- ☐ HV-03
- ☐ HV-05
- ☐ HV-07
- ☐ HV-08
- ☐ HV-09
- ☐ HV-11
- ☐ HV-12
- ☐ HV-14
- ☐ HV-16
- ☐ HV-17
- ☐ HV-18
- ☐ HV-016
- ☐ HVSKS
- ☐ HVUB
- ☐ HVUV

**20 meter shuttle run test protocol**

Appendix 4

HV-distrikt:_____________

Dato:_____________

| Level | Shuttle | v | ID-nr | Level | Shuttle | v | ID-nr | Level | Shuttle | v | ID-nr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 1 | | | **6** | 1 | | | **10** | 1 | | |
| | 2 | | | | 2 | | | | 2 | | |
| | 3 | | | | 3 | | | | 3 | | |
| | 4 | | | | 4 | | | | 4 | | |
| | 5 | | | | 5 | | | | 5 | | |
| | 6 | | | | 6 | | | | 6 | | |
| | 7 | | | | 7 | | | | 7 | | |
| | | | | | 8 | | | | 8 | | |
| **2** | 1 | | | | 9 | | | | 9 | | |
| | 2 | | | | | | | | 10 | | |
| | 3 | | | **7** | 1 | | | | 11 | | |
| | 4 | | | | 2 | | | | | | |
| | 5 | | | | 3 | | | **11** | 1 | | |
| | 6 | | | | 4 | | | | 2 | | |
| | 7 | | | | 5 | | | | 3 | | |
| | 8 | | | | 6 | | | | 4 | | |
| | | | | | 7 | | | | 5 | | |
| **3** | 1 | | | | 8 | | | | 6 | | |
| | 2 | | | | 9 | | | | 7 | | |
| | 3 | | | | 10 | | | | 8 | | |
| | 4 | | | | | | | | 9 | | |
| | 5 | | | **8** | 1 | | | | 10 | | |
| | 6 | | | | 2 | | | | 11 | | |
| | 7 | | | | 3 | | | | 12 | | |
| | 8 | | | | 4 | | | | | | |
| | | | | | 5 | | | **12** | 1 | | |
| **4** | 1 | | | | 6 | | | | 2 | | |
| | 2 | | | | 7 | | | | 3 | | |
| | 3 | | | | 8 | | | | 4 | | |
| | 4 | | | | 9 | | | | 5 | | |
| | 5 | | | | 10 | | | | 6 | | |
| | 6 | | | | | | | | 7 | | |
| | 7 | | | **9** | 1 | | | | 8 | | |
| | 8 | | | | 2 | | | | 9 | | |
| | 9 | | | | 3 | | | | 10 | | |
| | | | | | 4 | | | | 11 | | |
| **5** | 1 | | | | 5 | | | | 12 | | |
| | 2 | | | | 6 | | | | | | |
| | 3 | | | | 7 | | | | | | |
| | 4 | | | | 8 | | | | | | |
| | 5 | | | | 9 | | | | | | |
| | 6 | | | | 10 | | | | | | |
| | 7 | | | | 11 | | | | | | |
| | 8 | | | | | | | | | | |
| | 9 | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

HV-distrikt:_____________

Dato:_____________

| Level | Shuttle | v | ID-nr | Level | Shuttle | v | ID-nr | Level | Shuttle | v | ID-nr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **13** | 1 | | | **16** | 1 | | | **19** | 1 | | |
| | 2 | | | | 2 | | | | 2 | | |
| | 3 | | | | 3 | | | | 3 | | |
| | 4 | | | | 4 | | | | 4 | | |
| | 5 | | | | 5 | | | | 5 | | |
| | 6 | | | | 6 | | | | 6 | | |
| | 7 | | | | 7 | | | | 7 | | |
| | 8 | | | | 8 | | | | 8 | | |
| | 9 | | | | 9 | | | | 9 | | |
| | 10 | | | | 10 | | | | 10 | | |
| | 11 | | | | 11 | | | | 11 | | |
| | 12 | | | | 12 | | | | 12 | | |
| | 13 | | | | 13 | | | | 13 | | |
| | | | | | 14 | | | | 14 | | |
| **14** | 1 | | | | | | | | 15 | | |
| | 2 | | | **17** | 1 | | | | | | |
| | 3 | | | | 2 | | | **20** | 1 | | |
| | 4 | | | | 3 | | | | 2 | | |
| | 5 | | | | 4 | | | | 3 | | |
| | 6 | | | | 5 | | | | 4 | | |
| | 7 | | | | 6 | | | | 5 | | |
| | 8 | | | | 7 | | | | 6 | | |
| | 9 | | | | 8 | | | | 7 | | |
| | 10 | | | | 9 | | | | 8 | | |
| | 11 | | | | 10 | | | | 9 | | |
| | 12 | | | | 11 | | | | 10 | | |
| | 13 | | | | 12 | | | | 11 | | |
| | | | | | 13 | | | | 12 | | |
| **15** | 1 | | | | 14 | | | | 13 | | |
| | 2 | | | | | | | | 14 | | |
| | 3 | | | **18** | 1 | | | | 15 | | |
| | 4 | | | | 2 | | | | 16 | | |
| | 5 | | | | 3 | | | | | | |
| | 6 | | | | 4 | | | | | | |
| | 7 | | | | 5 | | | | | | |
| | 8 | | | | 6 | | | | | | |
| | 9 | | | | 7 | | | | | | |
| | 10 | | | | 8 | | | | | | |
| | 11 | | | | 9 | | | | | | |
| | 12 | | | | 10 | | | | | | |
| | 13 | | | | 11 | | | | | | |
| | | | | | 12 | | | | | | |
| | | | | | 13 | | | | | | |
| | | | | | 14 | | | | | | |
| | | | | | 15 | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

Anders Aandstad // Physical Fitness and Physical Activity in Norwegian Home Guard Soldiers