Importance of strength training for sustaining performance and health in military personnel

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ABSTRACT

The physical capacity of male and female warfighters is challenged on the modern battlefield by heavy loads and high-intensity work. When designing training programmes for warfighters, approaches for developing strength and power alongside endurance must be considered. Strength training often requires facilities that may not be available during deployments while multiple stressors may impair or decrease overall performance. Understanding the effect of military environments on warfighter performance and acknowledging the variation in demands for individuals during field training and deployments, including possible sex differences, is essential to promote the development of adequate physical reserves (strength, power and endurance), attenuate risk for injury and promote health during and after military careers. The purpose of this narrative review is to discuss considerations for programming physical training in a military environment where 'one size does not fit all'. In addition, a brief description of physiological contributions (neural and muscular) to strength development is included.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The physical capacity of warfighters is challenged on the modern battlefield by heavy loads, high-intensity work and multiple stressors.

WHAT THIS STUDY ADDS

⇒ Training programmes for warfighters require approaches for developing strength and power alongside endurance and may require individualised approaches considering fitness level, task-specific demands, military environment and sex differences.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Military organisations must invest resources in physically preparing personnel for the rigours of military service while preserving the fitness and health of the workforce throughout military careers. Physical preparation may require individualised approaches.

INTRODUCTION

Carefully planned, periodised, progressive and individualised physical fitness training can prepare warfighters to perform physically demanding occupational tasks at required levels during discrete activities and longer-term operations. Muscular strength, power and endurance are essential for performing most occupational tasks in military settings, as well as for maintaining or improving underlying health. The importance of muscular strength has been recognised in military environments, where occupational tasks for both male and female warfighters require repeated load carriage, loaded marching, manual material handling, such as lifting, digging, carrying, pushing, pulling and their combinations, as well as casualty evacuation.[1–3] In addition to heavy load carriage and aerobic work periods, the modern battlefield (eg, urban operations) often requires intensive actions including short, fast and anaerobic movements (eg, jumping over obstacles and climbing stairs). These manoeuvres may be conducted over large areas without a clearly defined front line. Future large-scale combat operations, in which peer adversaries conduct war, will require perhaps the highest levels of physical preparedness observed since World War II. Over recent decades, marching distances have shortened but the physical intensity of warfighting has increased.[4] Concomitantly, warfighters must often contend with additional operational stressors (eg, low energy availability, psychological stress and sleep deprivation) and environmental factors (eg, difficult terrain and extreme temperatures). Military operational stress can impact physical performance and circulating hormonal milieu while both operational environments and logistic constraints may limit access to strength training for maintaining or improving fitness. Importantly, the physical performance of individual warfighters may deteriorate very rapidly in operational environments, and there may be insufficient time to recover or improve physical performance between missions. As such, the importance of proper training for physical preparedness prior to military conflicts cannot be overemphasised by warfighters.

The purpose of this narrative review is to discuss considerations for programming physical training in a military environment where 'one size does not fit all'. We will focus on longer-term operations rather than discrete task performance as this has been covered by Vaara *et al*.[3]

STRENGTH TRAINING

Strength training is essential for developing muscle strength for transferring and moving body weight or generating force against external loads, such as in load carriage or in lifting and pushing tasks. Strength training can be used to develop specific and targeted parts of the neuromuscular system based on an individual's needs analysis, and development can be achieved through a variety of different training methods (Table 1). The design

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Table 1 Examples of strength training loads and military tasks.

Strength mode	Load	Purpose	Examples of military tasks/applications
Maximal (neural)	85%–100% RM	↑ neural function and strength, may also ↑ muscle mass	Lifting, digging, carrying, pushing, pulling and combinations
Maximal (hypertrophic)	60%–85% 1RM	↑ muscle mass and strength, accompanied by ↑ neural adaptations	Lifting, digging, carrying, pushing, pulling and combinations
Power	30%–80% 1RM	↑ fast-force production and activation of motor units of the neuromuscular system for maximal use	Lifting, rushes, sprints
Muscle endurance	0%–60% 1RM 15+ repetitions	↑ ability to repetitively produce submaximal force	Marching, lifting, digging, carrying, pushing, pulling and combinations

RM, repetition maximum.

of strength training programmes requires progression, variation and periodisation that includes overload and recovery. Training programme intensity, volume, choice and order of movements, rest between sets and recovery via periodisation influence the physiological events in the body that mediate responses that influence adaptations in physical performance including muscle hypertrophy, maximal force production, power and endurance.

PHYSIOLOGY OF STRENGTH TRAINING

Adaptations to strength training occur throughout the neuromuscular system (Figure 1). Initial increases in strength result from improvements in neural function, followed later by muscle hypertrophy. Neural adaptations include improvements in motor unit recruitment, increased motor unit synchronisation and a reduction in excitability of a contracted or stretched muscle. Skeletal muscle hypertrophy is a complex process resulting from an intricate interplay between external and internal variables that are not yet fully understood. It is known that activation of Mammalian Target of Rapamycin (mTOR) is a key component of muscle anabolism, but additional factors appear to contribute to skeletal muscle hypertrophy beyond this protein kinase. The observed changes occur in muscle cell quality, such as increased myofibril packing density and protein type, as myosin isoform changes from form X to form A. According to Kraemer *et al*, testosterone, growth hormone and insulin-like growth factors also play a major role in muscle cell development and growth, although specific hormonal effects should be considered in the context of the endocrine system as a whole and its connection to other physiological systems. In addition to these anabolic hormones, glucocorticoids and cortisol, in particular, influence human skeletal muscle anabolism due to their opposing effects.[5] Finally, recent work has illustrated the importance of extracellular vesicles (EVs) and EV miRNAS in targeting pathways involved in growth, metabolism and immune function following acute resistance exercise as contributing significant adaptive signalling cascades modulating training adaptations.[6] While greater force production has generally been accepted to increase the quality of the training stimulus, ultimately increasing the

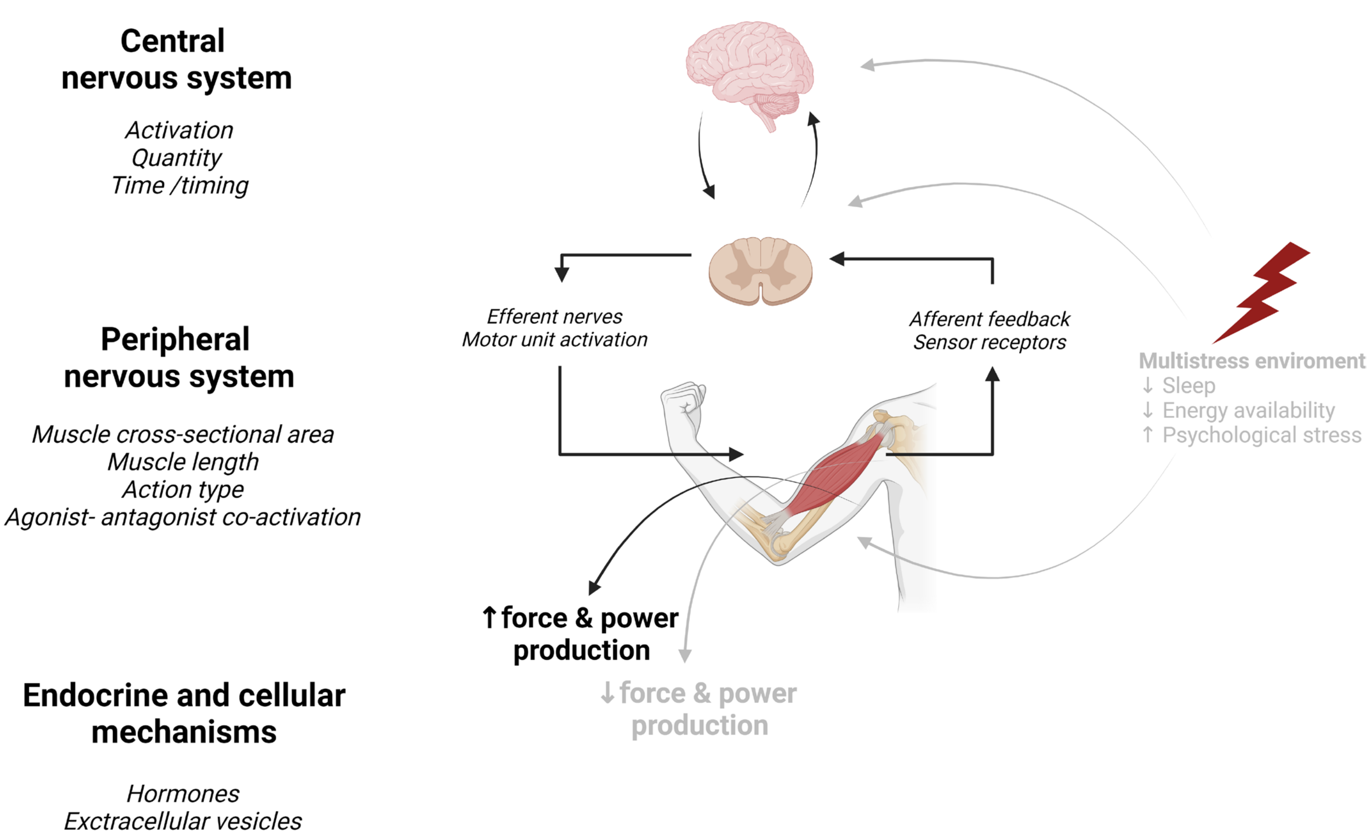

Figure 1 Schematic of factors affecting and contributing to strength training adaptations (figure produced using BioRender).

anabolic stimulation for hypertrophy, there is evidence that muscular adaptations can be obtained, or even optimised, using a wider spectrum of approaches to loading.[7]

SEX DIFFERENCES

Some sex differences should be considered in strength training and when examining strength training adaptations. It is generally accepted that females are less fatigable than males although this difference in fatigability is task-dependent and not explained by a single mechanism.[8] Generally, females have less muscle mass than males where muscle fibre type distribution and area favour oxidative type I fibres rather than type IIA fibres. Nevertheless, it appears that males and females adapt similarly to resistance training. A recent systematic review and meta-analysis revealed similar effect sizes for hypertrophy and lower-body strength following strength training but indicated that females had a larger effect for relative upper-body strength suggesting that when untrained, females have a higher capacity to increase upper-body strength than males.[9] The influence of strength training on strength, power and military occupational task performances in females has been investigated by Kraemer *et al* where it was determined that the gap between females and males (not participating in a training intervention) in terms of average absolute muscle strength can be significantly narrowed through strength training interventions emphasising loading targeted type II motor units (ie, heavier loads/fewer repetitions[10]). While females experience a similar decrease in physical performance as males during operational stress, females appear to experience greater physiological strain, however, this may be attributed to differences in absolute fitness levels.[11] At present, there is no robust evidence suggesting that strength training approaches in females should be any different than those in males[9] although the paucity of data regarding power development in females should be addressed in future research.

STRENGTH TRAINING FOR ESSENTIAL MILITARY TASKS

Although it is evident that warfighters need both aerobic and muscular fitness to successfully perform tasks and duties, the importance of muscular fitness (strength and power, table 1) has only been acknowledged within recent decades as an ever-increasing fundamental capability in military work.[3] The available evidence from physical training intervention studies demonstrates that strength training alone or combined with aerobic training is effective in increasing performance in essential military tasks.[3,12]

Several training intervention studies show positive training adaptations in load carriage performance, while strength training alone appears to be nearly as effective as combined strength and aerobic training to improve load carriage performance.[4] A recent study in recruits[13] showed that a training programme with an emphasis on strength training (63% of all training) induced better adaptations not only in load carriage but also in maximum box lift performance than traditional military physical training after 12 weeks of basic military training. Importantly, a greater improvement in load carriage performance was achieved despite a reduction in load carriage exposure when compared with the extant physical training programme. Similarly, adding two strength training sessions to warfighters' weekly training for 9 weeks, compared with the no-resistance training group, increased performance in load carriage as well as in fire and movement performances.[14] Recently, Sterczala *et al*[12] reported 7%–30% improvements in load carriage, as compared with the initial values, in manual material handling, and casualty evacuation performances after a 12-week strength and power training period that included interval training.[12] In female soldiers, the ability to perform physically demanding military occupational tasks improved significantly following concurrent training with an emphasis on load carriage and lifting for 6 months. At baseline, 24% of females qualified for current 'heavy' and 'very heavy' military occupational specialties, which increased to 78% after training.[15]

In addition to load carriage, current evidence suggests that manual material handling performances can be markedly improved with strength training, either alone or in combination with aerobic training.[3] Substantial improvements in manual material handling performances such as maximum or repetitive box lift (9%–47%) and lift and carry performances (7%–18%) have been observed with training programmes including more strength training over other training modalities.[12] Notably, Kraemer *et al*[10] showed improvements in maximal box lifting performance among groups with different resistance training emphases (hypertrophy vs power, total body vs upper body), while aerobic training did not improve lifting performance. In contrast to discrete lifting performance, all groups performing strength training, even in combination with aerobic training, improved repetitive lifting performance[10] indicating that developing physical characteristics via different training methods may contribute to lifting performance at an individual level.

Regarding various forms of casualty evacuation that may require maximal strength, power and/or endurance, there is less research available, and the existing training studies have primarily investigated combined strength and aerobic training programmes. These studies do, however, show that incorporating strength training into a physical training programme may improve casualty evacuation performance, measured as the completion time of dragging a 111 kg dummy backwards for 20 m as quickly as possible, by as much as 10%–30%.[12] Synthesising the current literature, several takeaway points emerge: (1) an effective and holistic physical training programme will include resistance training with special emphasis on strength and power development (ie, activation of high-threshold motor units and recruitment of type II high-force muscle fibres), (2) inclusion of upper-body strength development may be beneficial, particularly in female populations, (3) both resistance and endurance training are essential for the improvement of, for example, load carriage ability assessed by specific load carriage task performance and (4) providing greater equipment resources, coaching assets and increased dedicated physical training time may be warranted to achieve physical readiness in warfighters.

While strength training is often combined with endurance training when preparing warfighters for military operations, combining strength training with high volumes of endurance training is generally believed to be somewhat detrimental to strength and hypertrophy, particularly in explosive strength, in comparison to strength training alone. This so-called interference effect has not been observed in females[16] and untrained males although both trained males and females are under-represented in the literature.[17] Overall, substantial sex differences in approaches to combined strength and endurance training are not currently justified. The present literature suggests that higher load resistance training should be combined with lower intensity[18] or lower volume high-intensity aerobic training[19] to maximise strength gains and possibly also minimise losses after detraining, which may be relevant to military operations.

STRENGTH TRAINING IN THE MILITARY CONTEXT

Maintaining or increasing muscle strength and mass can be challenging for warfighters given the training and operational demands required. Demanding multistressor or extended field training activities or deployments can lead to decrements in physical capacity including muscular strength over both the short term and longer term. For example, Nindl *et al*[20] showed decrements in maximal strength, power and lean mass following a demanding 8-week training course. On the other hand, a recent meta-analysis of deployment studies (≥3 months) showed a small increase in both lower-body and upper-body maximal strength and no change in lean mass or lower-body power.[21] It must be acknowledged that operational environments for field training and deployments (eg, combat vs humanitarian or peacekeeping) can influence the ability of warfighters to maintain or increase muscular strength or lean mass. Understandably, the impact of field training and deployments on health and physical performance has been a research focus. Yet, these activities may comprise a relatively small perturbation to the through-career maintenance of strength and muscle mass when compared with other challenges including ongoing technical proficiency courses, promotion courses and career progression. This will obviously vary between warfighters, but collectively warfighters will encounter various challenges to the maintenance of strength and muscle mass via multistressor environments. Therefore, focusing on training and nutritional strategies to support the through-career maintenance of strength and muscle mass may be critical to mitigate detraining and preserve occupational performance. These strategies may include the microdosing of strength training when time-constrained and ensuring sufficient dietary protein intake, especially during periods of caloric deficit.

It is evident that strength training is important to warfighters for occupational task performance,[22] however, the importance of strength training extends far beyond supporting discrete task performance and associated resilience to injury.[3] Strength training also plays a critical role in preserving the health of warfighters. While there has been considerable research and public health focus on aerobic activity, strength training provides a multitude of health benefits. For example, strength training can arrest age-related declines in muscle mass and function, as well as bone mass.[23] Strength training, such as endurance training, can have beneficial effects on mental health[24] and has also been associated with lower all-cause mortality, cardiovascular disease, diabetes and some cancers.[25]

Progressive strength training can provide numerous health and performance benefits for warfighters, and by extension, support the preservation of organisational capability and readiness. While many of the aforementioned disease states may typically be considered most relevant to middle-aged and older adults, military organisations must be increasingly mindful of their associated morbidity and how to mitigate them for several reasons:

1. Current general population trends of decreasing physical fitness are invariably reflected in the recruit pool for many military organisations meaning that they are taking on a greater training burden (ie, lower training status and physical capacity) to physically prepare personnel for military service.
2. Many military organisations are seeking to increase workforce diversity, for example, females and early middle-aged adults.
3. Many disease states that have typically been prevalent in older adults are becoming increasingly prevalent in younger and middle-aged adults.
4. Many military organisations are experiencing recruitment pressures for several reasons including reduced ability to meet entry requirements and declining interest in joining the military. This also increases the imperative to maintain the existing workforce and mitigate health-related separations.

ONE SIZE DOES NOT FIT ALL

Strength training responses and adaptations may vary enormously between individuals. Variation may be due to age, training status, sex, genetic and environmental factors[26] as well as nutrition.[27] Strength training generally improves physical performance where adaptations may be specific to the strength training programmes (including exercise choice, load and velocity of movements, ie, strength/power vs strength/hypertrophy). The magnitude of sex differences in physical performance measures is reported to decrease after strength training in females[10] whereas in females, upper-body and total-body resistance training may yield similar improvements in occupational task performances, especially those involving the upper body.[10] Nevertheless, an emphasis on whole-body resistance training rather than upper-body training is recommended.

Individual variation in physical fitness including maximal strength and muscle fitness development exists in many of the military environments. The commencement of military service is typically a physically demanding period for recruits and conscripts, and the existing evidence clearly shows an inverse correlation between baseline physical fitness and development of fitness during initial training.[28] Specifically, those commencing military training with lower physical fitness tend to have a higher risk for injury incidence[29] and demonstrate greater training gains when compared with those with higher fitness. This is not surprising given the fixed course programmes (eg, fixed number and duration of physical training lessons) and the group training environment. However, there is an opportunity for military organisations to adopt more contemporary physical conditioning methods[13] to increase individualisation and yield greater gains in physical fitness across the entire cohort. Individual responses have also been reported during the early career of professional warfighters[30] and while on deployment.[28]

In the military context, that is, in a multistressor environment, careful planning, periodisation and progressive physical fitness training can help warfighters to reach required performance levels for specific occupational tasks before missions and operations while simultaneously benefiting warfighters' long-term health. As such, strength training should be tailored, when possible, to task-specific demands and to the individual as well as to the environment. Furthermore, before long deployments, where there are often limited opportunities for physical training, it is important to create a sufficient buffer so that possible detraining does not compromise warfighters' ability to perform key tasks.

CONCLUSIONS

The physical performance demands imposed on warfighters highlight the importance of strength and power training. Military organisations must invest effort in physically preparing personnel for the rigours of military service while preserving the fitness and health of the workforce throughout military careers.

1. Most military tasks require muscular fitness (muscle strength and muscle endurance) for performance while muscular fitness is also important for long-term health.
2. The multiple stressors that are present in operational environments may influence the ability to train, training adap-

tations and maintenance of muscular fitness. These factors should be considered during preparation for, and while on deployments. Several strategies may be employed to mitigate potential detraining.

3. Individual training programmes are difficult to apply in military settings but there is the opportunity to apply contemporary training methods to increase the individual training stimulus within group training environments while supplementing with individualised training programmes to improve physical readiness across the workforce.
4. There is currently sufficient evidence and supporting technology to underpin the establishment of organisation-wide programmes to meet workforce health and performance imperatives but buy-in from senior leadership and resourcing are also fundamental inputs that should not be overlooked.

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