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Optimising Training Adaptations and Performance in Military Environment

Short title: Optimising physical training in soldiers

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Abstract

Objectives: Worldwide decreases in physical fitness and increases in body fat among youth have set challenges for armed forces to recruit physically capable soldiers. Therefore, knowledge of optimizing physical adaptation and performance through physical training is vital. In addition, maintaining or improving physical performance among professional soldiers in various military environments is crucial for overall military readiness. The present review focuses on the effects of military training on physical performance by searching for optimal methods to do it.

Design and Methods: Review article based on selected literature searches using the main keywords 'physical performance' and 'training' and 'military' from MEDLINE and SportDiscus® engines. Additional selected references were included that encompassed the same words but were not found in the present search.

Results: Military training mainly consists of prolonged physical activities and training performed at low-intensities, which may interfere with optimal muscle strength and considering development of maximal strength, power, and aerobic capacity. Combined

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endurance and strength training seems to be a superior training method to improve overall physical performance of soldiers.

Conclusions: The present study demonstrated that military training needs a greater variation in training stimulus to induce more effective training adaptations, especially, when considering the development of maximal or explosive strength and maximal aerobic capacity. Training programs should be well periodised so that total training load increases progressively but also includes sufficient recovery periods. In addition, some individualized programming is required to avoid unnecessary injuries and overloading because the differences in initial physical fitness of soldiers can be very high.

Keywords: soldier, strength, endurance, body composition

Introduction

The average aerobic fitness of young men entering military service has declined and has been accompanied by a simultaneous increases in body mass, especially in western countries.[1,2] At the same time, however, it is well recognised that successful performance of military duties requires a high level of physical fitness, especially, aerobic fitness and muscular strength.[3,4] Physical training, of which specific aims vary in relation to the phase of a soldier's career, is the most effective method to improve or maintain physical performance. The goal of military basic training (BT), for example, is to reach an employment standard level or a level of physical performance needed during the following training phases. For professional soldiers, the focus is to reach or maintain the physical performance level required for deployment and occupation. The outcome of physical training programs depends on training volume (duration, distance or repetitions), intensity (load, velocity or power) and frequency, which are key factors of training. In sports training, total training load, nutrition and recovery are typically planned in an individual way in order to optimise training adaptations and minimise training-related injuries and overtraining. Similarly, when designing a training plan in a military environment, the coach, tactical strength and conditioning facilitator, or military instructor must first decide which factors to emphasise in

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order to meet the performance goals or task requirements. At the same time, it is important that these emphasised training factors are also well in proportion with the trainee's individual needs and initial fitness level, and that the training plan is well periodised.

In general, several factors such as age, sex, training history, recovery, sleep and nutrition, as well as environmental, psychological, and social factors can significantly affect training adaptations. In addition, optimising performance in military environments is often challenged by external stress factors such as prolonged physical activity while carrying loads, negative energy and fluid balance, sustained readiness, and sleep deprivation.[5-7] Therefore, training load combined with these external stress factors can lead to compromised training adaptations and/or overreaching and overtraining in addition to increased musculoskeletal injury rates.[8-10] These factors should be taken into account when planning and implementing optimal training programs for soldiers. Figure 1 summarizes factors affecting optimal development of soldiers' physical performance and, therefore, operational readiness.

As mentioned earlier, a variety of factors, which differ individually, have influences on soptimised training adaptations in military environments. In recruits, military training consists of a high amount of low-intensity physical activity, which can be a challenge for optimising improvements in strength performance.[11] For professional soldiers, on the other hand, the challenges arise more from reaching and maintaining the performance level set for more demanding occupational requirements or deployment standards. Furthermore, due to physiological sex differences, female soldiers are often required to increase their physical fitness to a greater extent compared to male soldiers.[12,13] In particular, tasks involving extra loads or carry and lifting heavy materials seem to be more challenging for female soldiers due to their smaller body size and lower muscular fitness levels. Therefore, physical fitness demands are relatively higher for female soldiers compared to those of male soldiers.[14] Training principles and periodisation in endurance and strength training are essentially the same for both sexes.[13]

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The present review aimed to explore studies that have attempted to improve physical performance by optimising physical training adaptations in military environments in both recruits and professional soldiers. In addition, possible mechanisms for suboptimal adaptations and optimisation of training strategies are discussed.

Design and methods

The present review focuses on the military training effects on physical performance. The articles have been selected from literature searches using the keywords 'physical performance' and 'training' and 'military' from MEDLINE and SportDiscus® search engines. Additional selected references were included that encompassed the same words but were not found in the present search. All together, we found almost 200 published articles, of which 60 were selected for this review according to inclusive criteria of the main keywords. The published articles mainly focused on male army soldiers who can be further divided into two main categories; recruits or conscripts with no prior experience performing military duties, and professional soldiers.

Endurance training

Traditionally, endurance training in the military has consisted of moderate-intensity running, walking or marches with or without load carriage at a constant speed.[11] Santtila et al.[11] found that additional endurance training during military BT did not produce additional gains in aerobic fitness. Despite this finding, moderate intensity aerobic training, such as marching with extra loads, is still a widely used training method in the military. Recent studies have suggested that high-intensity interval training (HIIT) will induce similar or superior training responses compared to moderate-intensity endurance training with less time commitment.[15] HIIT refers to a training mode that involves repeated, relatively brief bouts at high intensity interspersed with lower intensity periods of recovery.[15,16] HIIT has been shown to induce greater neuromuscular adaptations than traditional endurance training.[17] Thus, a low volume

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of HIIT may elicit a higher neuromuscular training effect and thereby may better induce developments in strength performance as a part of combined training. Nevertheless, to date there are only a very few HIIT studies implemented in military environments.[15]

Knuttgen et al.[18] compared adaptations to HIIT in three training groups of conscripts. Each group performed HIIT by running 15 min per session, with one group performing 5 training sessions per week for one month, and the other two groups 3 sessions per week for two months. In total, all groups had 19 training sessions during the study period. The improvement in maximal aerobic capacity was around 20% in all groups. Kilen et al.[19] studied training adaptations of professional soldiers in two training groups: one performing nine 15-min training sessions per week ("microtraining") and the other performing three 45-min sessions ("traditional training") during 8 weeks with sessions of strength, high-intensity endurance training and muscle endurance. Both groups improved shuttle run performance but only the "microtraining" group improved peak oxygen uptake, grip strength, and loaded lunge performance. Finally, the authors concluded that short and more frequent training sessions can induce at least similar training adaptations compared to longer and less frequent sessions.

Gist et al.[20] studied the effects of HIIT training performed as calisthenics, otherwise known as high-intensity functional training (HIFT) in twenty cadets. The participants performed a 4-week training period with 3 exercises per week either in a group with typical physical training (combined endurance and muscular endurance exercises) or HIFT. The typical training group performed 60-min workouts consisting of one running exercise with moderate intensity, one exercise of self-paced load carriage, and one exercise of moderate intensity running followed by calisthenics. The HIFT group performed 4 to 7 sets of 30 s "all-out" burpees with 4 min of active recovery. The performance of aerobic and anaerobic capacity, and muscular endurance were unchanged and revealed no differences between the groups.

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Thus, the authors concluded that HIFT might be a suitable training method to maintain fitness.

In conclusion, HIIT and HIFT can be recommended for soldiers mainly for its superior or similar training responses compared to moderate-intensity endurance training but as a less time devoted training modality. In addition, for recruits and conscripts HIIT and HIFT may provide an essential training stimulus that differs from their service-related high volume of low-intensity endurance type of activity. Furthermore, from practical point of view HIIT/HIFT may be considered an accessible and easily individualised in soldiers, especially, under operational and field conditions. However, when HIIT/HIFT is applied in the physical training program a special caution should be placed on overall physical loading to avoid overtraining.

Strength training

During increasingly physically-demanding military operations, maximal strength and power are vital parts of modern physical training and operational readiness of soldiers.[21] For optimal performance of military tasks (e.g. lifting or carrying heavy loads, casualty drag, sprinting or climbing obstacles, patrolling in variable terrain), the development of strength and power should be an essential part of soldiers' regular training.[22] Maximal muscle strength can be improved by increasing muscle size due to a hypertrophic training or by increasing the role of neural factors by power training.[23] Prolonged military field training and operations have been shown to lead to a decrease in muscular strength and power.[24,25]

Vantarakis et al.[26] studied specific conditioning of muscle endurance and strength among Naval Academy cadets for an 8-week study period when the experimental group participated in a linear periodised strength training program in addition to their daily training. The exclusive training of the experimental group included uni- and multilateral resistance training exercises such as squats, deadlifts, lunges, bench presses, arm curls etc. Unlike the control group, the experimental group showed improvements in upper and lower-body maximal strength, power, and time to complete occupational obstacle course. Thus, additional

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strength training seems to improve both physical and occupational performance of navy cadets.

In a study of Lester et al.[27], a novel 7-week physical training program was compared with traditional Army physical fitness training. The experimental training included core stability, flexibility, resistance training, agility, speed, and power exercises, whereas the traditional army physical training group completed their normal fitness training including calisthenics and aerobic exercises. In these previously trained soldiers, greater improvements were observed in the experimental group for maximal strength, power and for one occupational test, namely casualty recovery time. However, similar improvements were observed for both groups in the agility drill and vertical jump height, and pull-up performance.

It must be noted that strength training interventions in military environments should partly be regarded as combined training due to the aerobic nature of military training itself, especially, during military BT in recruits or conscripts. Moreover, for professional soldiers, endurance training is always integrated into their total training program; thus, limited research is available investigating strength training adaptations alone.

In conclusion, non-optimal adaptation to added strength training during initial military training may be a result of interference effect. Thus, periodisation of strength and endurance training may improve adaptations to strength training. The programming of strength training should be planned carefully, taking into account the training load from endurance type of military activities such as marching and field exercises.

Combined strength and endurance training

Military training and operations consist of tasks that can be attained through combined strength and endurance training.[28] Therefore, it can be concluded that combined strength and endurance training is the foundation of soldiers' physical performance.[29] The combined

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training may well induce positive training adaptations both in aerobic fitness and muscle strength capabilities in poorly-conditioned, overweight and inactive individuals.[28] However, training adaptations are being compromised in more fit and active individuals. This phenomenon is called interference effect, which was first established by Hickson et al.[30] The interference on optimal strength training adaptations may be caused by high volumes of endurance type of activity, which is a typical characteristic of military training. This combination has been shown to inhibit signaling mechanisms of protein synthesis and thus responses can be observed both at the molecular level[31-32] as well as the systemic level[33-34]. Therefore, combined strength and endurance training may hamper training responses, especially for strength development, when compared to training either exercise mode alone. The interference of combined training may be avoided or, at least, reduced by using optimal training programming and periodisation. However, in recruits or poorly-conditioned soldiers, all types of training most likely improve physical performance without a risk for interference.

Many studies have shown that the initial, typically 7- to 10-week standardized military BT period has positive effects on physical performance and body composition of the recruits[35-37], as well as on performance of military occupational specialties[38]. Improved aerobic fitness and muscular strength of up to 10-15% in eight weeks have been observed, especially in recruits or conscripts with lower levels of initial fitness.[9,11,37] During the following military training phases, nevertheless, adaptations may not have been optimal in relation to total training volume, and some of the performance gains may have been compromised.[35,39] Therefore, physical training interventions, before and during the initial military training periods, have been conducted aiming to improve optimization of training adaptations .

Some studies have suggested that a preparatory physical training intervention (performed 4-8 weeks before military service) for recruits , may improve training adaptations for military BT while reducing the risk for musculoskeletal injuries.[40-42] These findings are important when keeping in mind that the average aerobic fitness level of young men entering military

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service has declined along with a simultaneous increases in body mass.[1,2] Thus, it is more challenging to meet the goals of military training during the initial training phases of the service. Chai et al.[42] found a preparatory 6-week physical training program beneficial in terms of aerobic capacity for those with a lower initial fitness level. The progressive preparatory training consisted of 197 hours of strength and endurance training, flexibility and motor skill training, and theoretical education. The unfit recruits reached the average aerobic fitness level of the study population by the end of the BT period.[42] This is an important finding since it is better to execute standardised BT when there is less variation in the physical fitness of soldiers.

A number of training intervention studies have been conducted during the BT period. For example, Santtila et al.[11,33] observed improvements in maximal aerobic capacity, load carriage performance, and maximal strength of both upper and lower extremities of conscripts during the BT period. In addition, they found that all beneficial changes in physical performance and body composition were particularly prominent among previously inactive young men. However, the strength training group did not improve strength or muscle hypertrophy to a greater extent than the aerobic intervention group or a group with normal military BT. Moreover, Hofstetter et al.[36] reported that additional outdoor circuit training induced greater increases in trunk strength and aerobic capacity, whereas no difference was observed in power of the upper and lower body. Furthermore, Sporis et al.[43] studied the effects of two different 5-week training programs on the physical fitness of military recruits. A total of 124 recruits were divided into continuous endurance and relative strength training (CERS) and basic military physical readiness training (BMPR) groups. Both groups trained three times per week for 1.5 to 2 hours per day. As a result, both groups improved their physical readiness, but BMPR established greater advances in some motor abilities while CERS achieved greater improvements in endurance tests.

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One example of training optimization development is the U.S. Army Physical Readiness Training (PRT). This training program was based on a thorough task analysis of a soldier and aimed for a simultaneous reduction in injuries. PRT included reduced running mileage, more gradually progressive periodisation and exercise variety and has been shown to lead to similar or improved training adaptations and lower injury rates compared to traditional Army physical training.[44]

However, in terms of physiological adaptations, conflicted findings have been observed in many studies. Additional gains in the measured variables were observed in some studies[43] while no changes or decreases in physical performance were found in other studies[11,33,45]. For example, Vaara et al.[46] compared the effects of a block-periodised resistance training protocol performed twice a week with military training over an 8-week special military training period. The intervention did not lead to improved maximal strength compared to the control group and. In fact, maximal strength of the lower extremities was reduced in both groups. It can be speculated that training frequency of two times a week was not a sufficient training stimulus for optimal muscle strength adaptions, or that the adaptations were interfered with strenuous military training that was primarily endurance type training. Nevertheless, both groups improved their load carriage performance, measured by 3.2 km running with a combat gear.

Possible explanations for the suboptimal adaptations to military training include high overall training volume and unilateral prolonged low-intensity endurance activity with inadequate recovery, which may lead to overtraining.[47,48] The same attributes typically increase the risk for musculoskeletal injuries, especially in low-fit service members[9,49] who are cigarette smokers[50]. In addition to low fitness level and smoking, female sex, high running mileage (or mileage on foot), high body mass index, and prior injury history have been recognized as major risk factors for injuries in many military studies[2,51]. On the other hand, the same absolute training volume may be optimal for a low-fit recruit but too low for a high-fit recruit.[33]

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The main findings of selected training adaptation studies in military environments are presented in table 1.

Despite the interference effect in high-fit individuals such as special operators, a well-design periodisation of the training program is required for improving physical performance. Thus, some studies have concentrated on physical training interventions in professional soldiers, mainly in special force operators[25,52,53] and interventions on military occupational specialties, such as load-carriage performance[54]. Abt et al.[53] studied the effects of block-periodised and non-linear periodised training in Naval Special Warfare operators with 85 soldiers during 12 weeks. The experimental block training group trained with three 4-week blocks starting with aerobic endurance, muscular strength and coordination training followed by power and strength endurance and mixed endurance training. The third block aimed to improve power, strength, and high intensity tactical drills. The control group trained with a non-linear periodisation program that included training increments after every two weeks. For the first block, over the course of a week the program consisted of whole-body resistance training for one day, Olympic lifts and strength exercises followed by short high-intensity intervals for two days, a high-intensity interval strength training for one day, and a slow endurance session each for two days. The second block focused on tactical-specific conditioning for two days, high-intensity interval cross training for two days, and a slow endurance session for one day. Both groups improved maximal aerobic capacity and standing long jump, medicine ball throw, and pull-ups. In addition, the experimental group improved agility runs and deadlift. On the contrary, neither group improved isokinetic maximal strength. In fact, decreases were observed for upper and lower body strength in experimental group, whereas the control group decreased in trunk flexion.

Solberg et al.[52] studied the effects of block training consisting of a 6-month linear periodisation period followed by a 6-month non-linear periodisation period in 22 operators serving in Navy Special Operations Command. The training programs emphasized either

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strength or endurance with block periodisation including 5-6 sessions per week. Linear periodisation included hypertrophic strength training, mixed endurance training, and typical strength training (4x5RM) followed by maximum strength training. In the non-linear periodisation, the training varied between blocks of endurance and strength training. The initial linear periodisation resulted in small to moderate training adaptations (ranging from -1 to +20%) followed by smaller adaptations (ranging from -10 to +15%) in non-linear periodisation. However, as the authors reported, even small improvements in physical fitness in soldiers with a high baseline level may be considered important.

Military occupational specialties may largely vary depending on military branch. To date, there are some studies available that are specifically targeted to improve these special demands. One of the most studied military tasks is load carriage, which is a highly relevant and required task in most of the branches of the military, especially in combat units. A meta-analysis[54] combined results from ten original physical training intervention studies, which aimed to improve load-carriage performance. The authors concluded that strength and endurance training alone had smaller effects with substantial variation compared to combined strength and endurance training, progressive load-carriage training, and field-based training including load carriage exercises. The most effective training mode to improve load-carriage performance was load-carriage exercises when they were progressively integrated as a part of the training program. In addition, significant training adaptations were found for combined strength and endurance training, as well as for field-based exercise such as plyometrics, agility training, sandbag lifts, and load-carriage Furthermore, O'Neal et al.[55] raised concerns of increased injury risk of such training modality, especially for female and low-fit soldiers.

It has also been shown that sex differences exist in most of the physical and military occupational performance variables, which mainly remain unaltered after military BT.[56] To date, there exists only a few training intervention studies exclusively focused on females in

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military environments.[54,57,58] In addition, some papers have been published including female and male soldiers as participants but the results have not been presented by sex.[25,59] Williams et al.[54] showed that added resistance training during 11-week military BT improved, in relative terms, occupational performance equally in both sexes. In the same study, the female recruits improved their maximal aerobic capacity in relation to their body mass by 18% while the respective change in males was only 8%.

In conclusion, compared to either strength or endurance training alone, combined training induces superior adaptations to soldiers' physical performance. Due to the physical demand of the profession and the need for continued military readiness, it is unavoidable to train only strength or endurance in military environment. However, several factors should be individually taken into account such as the initial fitness level, training history, task requirements, and periodisation of training.

Conclusions and Practical Applications

High volumes of low-intensity endurance training during initial military training phases leads to compromised training adaptations and in the worst cases, musculoskeletal injuries. Particularly low-fit, inactive, overweight recruits and female sex form a risk-group in this regard. For high-fit recruits, injury risk is lower but similarly, high volume and monotony in the training stimulus leads to stalling of performance, especially development of strength in military environment. Several modifications exist to increase variation in training stimulus such as progressively increased training load, individualisation or more variability in training modes. Physical taskrequirements should be the basis for goal setting in military training.

A progressive increase in training load should be carefully planned throughout the initial training period. Progression can only be achieved through some level of individualisation of training. One option to adapt low-fit recruits to the physical stress of military training is a preparatory training intervention before the actual military service. Some individualization

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may be achieved by dividing the recruits into groups according to their initial fitness level in the beginning of the BT training period. Thereafter, adjustments can be made to the total training load by varying the volume and intensity of the exercises between the groups. This method might result in improvements in the fitness of also high-fit recruits, whose maximal aerobic capacity has been shown to even decline during the latter part of their military service.[34] In this regard, it must be kept in mind that the nature of military training per se, is mainly high-volume and low-intensity endurance training. Thus, there may not be a need to implement physical training consisting of low-intensity endurance activities as a part of military training. A gradual increase in endurance exercise intensity adds variation to military training and may induce greater improvements in training adaptations. HIIT/HIFT may effectively improve physical fitness, both aerobic capacity and neuromuscular performance, with less time devoted to training as compared to low or moderate-intensity training.[15,20] Moreover, HIIT/HIFT can be considered as a practical training method for soldiers whenever time allocated to training and access to fitness facilities are limited, like in field conditions. HIIT/HIFT may even be performed in operational environments or during operations where decrements in aerobic performance have been observed. Nevertheless, its application in military environment should always be evaluated in relation to the composition of the rest of the physical training combined with other possible external stress factors. In addition, long-term HIIT/HIFT studies (>8 weeks) concentrating on physical performance, body composition, and injury incidence in the military settings are warranted.

As mentioned earlier, non-optimal adaptations to added strength training during initial military training may be a result of the interference effect. Block periodisation of strength and endurance training may improve adaptations to both training modalities, especially strength, in military environments. The planning of strength training blocks should be done carefully, taking into account the training load from endurance type military training, such as marching and field exercises. In addition, proper nutrition and time for recovery should be planned to optimise the effects of the strength training stimulus.[60] Proper strength training sessions

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might be possible to implement during theoretical education, basic shooting skills, and material handling training phases when the endurance training volume is low. Future studies are needed to elucidate whether positive strength training adaptations can be achieved during field exercises if adequate nutrition and recovery are simultaneously provided.

As the number of female soldiers is increasing, more focus should be paid on optimising their physical performance in relation to their task requirements in military environments. Surprisingly, only a few training studies on female soldiers have been published. Furthermore, in military training studies that use both sexes as subjects, the results should be reported by sex. This would give more information on the possible differences in adaptation between male and female soldiers.

In conclusion, practical recommendations should be based on the traditional nature of military training, which consists of high-volume and low-intensity endurance training with extra load of 25 to 65 kg. Therefore, progressively increasing combined endurance and strength and power training, possibly including in some extent high intensity interval training or microtraining, can be seen to induce superior adaptations in soldiers' physical performance. For achieving optimal physiological adaptations and, therefore, more effective development in physical performance, increasing attention should be paid to progressive and individualised training programs and their division into phases that sequentially develop performance. Thus, a personalised approach to performance optimisation should be emphasised when improving physical fitness and enhanced operational readiness of soldiers.

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REFERENCES

1. Santtila M, Kyröläinen H, Vasankari T, et al. Physical fitness profiles in young Finnish men during the years 1975-2004. *Med Sci Sports Exerc* 2006; 38:1990-1994.
2. Knapik J, Sharp M, Steelman RA. Secular trends in the physical fitness of United States Army recruits on entry to service, 1975-2013. *J Strength Cond Res* 2017; 31:2030-2052.
3. Sharp MA, Patton JF and Vogel JA (1998) A database of physically demanding tasks performed by US Army soldiers. T98-12, 1-42. Natick, MA, USA Army Research Institute of Environmental Medicine Technical Report. 3-10-0098.
4. Hauschild VD, DeGroot DW, Hall SM, et al. Fitness tests and occupational tasks of military interest: a systematic review of correlations. *Occup Environ Med* 2017; 74: 144-153.
5. Tharion W, Lieberman H, Montain S, et al. Energy requirements of military personnel. Appetite 2005; 44:47-65.
6. Booth CK, Probert B, Forbes-Ewan C, et al. Australian army recruits in training display symptoms of overtraining. *Mil Med* 2006; 171:1059-1064.
7. Henning P, Park B-S, Kim J-S. Physiological decrements during sustained military operational stress. *Mil Med* 2011; 176:991-997.
8. Knapik JJ, Sharp MA, Canham-Chervak M, Hauret K, Patton JF, Jones BH. Risk factors for training-related injuries among men and women in basic combat training. *Med Sci Sports Exerc* 2001, 33:946-954.
9. Rosendal L, Langberg H, Skov-Jensen A, et al. Incidence of injury and physical performance adaptations during military training. *Clin J Sport Med* 2003; 13:157-163.
10. Tanskanen MM, Uusitalo AL, Kinnunen H, et al. Association of military training with oxidative stress and overreaching. *Med Sci Sports Exerc* 2011a; 43:1552-1560.
11. Santtila M, Kyröläinen H, Häkkinen K. Changes in maximal and explosive strength, electromyography, and muscle thickness of lower and upper extremities induced by combined strength and endurance training in soldiers. *J Strength Cond Res* 2009; 23:1300-1308.

ACCEPTED MANUSCRIPT

ACCEPTED MANUSCRIPT

12. Courtright SH, McCormick BW, Postlethwaite BE, et al. A meta-analysis of sex differences in physical ability: revised estimates and strategies for reducing differences in selection contexts. *J Appl Psychol* 2013; 98:623-641.
13. Nindl BC, Jones BH, Van Arsdale SJ, et al. Operational physical performance and fitness in military women: physiological, musculoskeletal injury, and optimized physical training considerations for successfully integrating women into combat-centric military occupations. *Mil Med* 2016; 181:50-62.
14. Epstein Y, Yanovich R, Moran DS, et al. Physiological employment standards IV: integration of women in combat units physiological and medical considerations. *Eur J Appl Physiol* 2013; 113:2673-90.
15. Gibala MJ, Gagnon PJ, Nindl BC. Military applicability of interval training for health and performance. *J Strength Cond Res* 2015; 29 Suppl 11:S40-45.
16. Buchheit M, Laursen PB. High-intensity interval training, solutions to the programming puzzle: Part I: cardiopulmonary emphasis. *Sports Med* 2013; 43:313-338.
17. Martinez-Valdes E, Falla D, Negro F, et al. Differential motor unit changes after endurance or high-intensity interval training. *Med Sci Sports Exerc* 2017; 49:1126-1136.
18. Knuttgen HG, Nordesjö LO, Ollander B, et al. Physical conditioning through interval training with young male adults. *Med Sci Sports* 1973; 5:220-226.
19. Kilen A, Hjelvang LB, Dall N, et al. Adaptations to short, frequent sessions of endurance and strength training are similar to longer, less frequent exercise sessions when the total volume is the same. *J Strength Cond Res* 2015; 29 Suppl 11:S46-51.
20. Gist NH, Freese EC, Ryan TE, et al. Effects of low-volume, high-intensity whole-body calisthenics on army ROTC cadets. *Mil Med* 2015; 180:492-498.
21. Kraemer WJ, Szivak TK. Strength training for the warfighter. *J Strength Cond Res* 2012; 26 Suppl 2:S107-118.
22. Friedl KE, Knapik JJ, Häkkinen K, et al. Perspectives on aerobic and strength influences on military physical readiness: report of an international military physiology roundtable. *J Strength Cond Res* 2015; 29 Suppl 11:S10-23.

ACCEPTED MANUSCRIPT

ACCEPTED MANUSCRIPT

23. Moritani T, deVries H. Neural factors versus hypertrophy in the time course of muscle strength gain. *Am J Physiol Med* 1979; 58: 115-130.
24. Nindl BC, Barnes BR, Alemany JA, et al. Physiological consequences of U.S. Army Ranger training. *Med Sci Sports Exerc* 2007; 39:1380-1387.
25. Sporis G, Harasin D, Bok D, et al. Effects of a training program for special operations battalion on soldiers' fitness characteristics. *J Strength Cond Res* 2012; 26:2872-2882.
26. Vantarakis A, Chatzinikolaou A, Avloniti A, et al. A 2-month linear periodized resistance exercise training improved musculoskeletal fitness and specific conditioning of navy cadets. *J Strength Cond Res* 2017; 31:1362-1370.
27. Lester ME, Sharp MA, Werling WC, et al. Effect of specific short-term physical training on fitness measures in conditioned men. *J Strength Cond Res* 2014; 28:679-688.
28. Santtila M, Pihlainen K, Viskari J, et al. Optimal physical training during military basic training period. *J Strength Cond Res* 2015; 29 Suppl 11:S154-7.
29. Kraemer WJ, Vescovi JD, Volek JS, et al. Effects of concurrent resistance and aerobic training on load-bearing performance and the Army physical fitness test. *Mil Med* 2004; 169:994-999.
30. Hickson RC. Interference of strength development by simultaneously training for strength and endurance. *Eur J Appl Physiol Occup Physiol* 1980; 45:255–263.
31. Hawley JA. Molecular responses to strength and endurance training: are they incompatible? *Appl Physiol Nutr Metab* 2009; 34: 355-61. Review.
32. Fyfe JJ, Bishop DJ, Stepto NK. Interference between concurrent resistance and endurance exercise: molecular bases and the role of individual training variables. Sports Med 2014; 44:743–762.
33. Santtila M, Häkkinen K, Karavirta L, Kyröläinen H. Changes in cardiovascular performance during an 8-week military basic training period combined with added endurance or strength training. *Mil Med* 2008; 173:1173-1179.

ACCEPTED MANUSCRIPT

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34. Ihalainen JK, Schumann M, Eklund D, et al. Combined aerobic and resistance training decreases inflammation markers in healthy men. *Scand J Med Sci Sports* 2017; doi: 10.1111/sms.12906.

35. Santtila M, Häkkinen K, Nindl BC, et al. Cardiovascular and neuromuscular performance responses induced by 8 weeks of basic training followed by 8 weeks of specialized military training. *J Strength Cond Res* 2012; 26:745-751.

36. Hofstetter MC, Mäder U, Wyss T. Effects of a 7-week outdoor circuit training program on Swiss Army recruits. *J Strength Cond Res* 2012; 26:3418-25.

37. Mikkola I, Keinänen-Kiukaanniemi S, Jokelainen J, et al. Aerobic performance and body composition changes during military service. *Scand J Prim Health Care* 2012; 30:95-100.

38. Drain J, Billing D, Neesham-Smith D, et al. Predicting physiological capacity of human load carriage - a review. *Appl Ergon* 2016; 52:85-94.

39. Groeller H, Burley S, Orchard P, et al. How Effective Is Initial Military-Specific Training in the Development of Physical Performance of Soldiers? *J Strength Cond Res* 2015; 29 Suppl 11:S158-62.

40. Lee L, Kumar S, Kok WL, Lim CL. Effects of a pre-training conditioning programme on basic military training attrition rates. *Ann Acad Med* 1997; 26:3-7.

41. Knapik JJ, Darakjy S, Hauret KG, et al. Increasing the physical fitness of low-fit recruits before basic combat training: an evaluation of fitness, injuries, and training outcomes. *Mil Med* 2006; 171:45-54.

42. Chai LY, Ong KC, Kee A, et al. A prospective cohort study on the impact of a modified Basic Military Training (mBMT) programme based on pre-enlistment fitness stratification amongst Asian military enlistees. Ann Acad Med 2009; 38:862-868.

43. Sporis G, Harasin D, Baić M, et al. Effects of two different 5 weeks training programs on the physical fitness of military recruits. *Coll Antropol* 2014; 38 Suppl 2:157-164.

ACCEPTED MANUSCRIPT

ACCEPTED MANUSCRIPT

44. Knapik JJ, Rieger W, Palkoska F, et al. United States Army physical readiness training: rationale and evaluation of the physical training doctrine. *J Strength Cond Res* 2009; 23:1353-1362.

45. Harman EA, Gutekunst DJ, Frykman PN, et al. Effects of two different eight-week training programs on military physical performance. *J Strength Cond Res* 2008; 22:524-534.

46. Vaara JP, Kokko J, Isoranta M, et al. Effects of added resistance training on physical fitness, body composition, and serum hormone concentrations during eight weeks of special military training period. *J Strength Cond Res* 2015; 29 Suppl 11:S168-72.

47. Booth CK, Probert B, Forbes-Ewan C, et al. Australian army recruits in training display symptoms of overtraining. *Mil Med* 2006; 171:1059-1064.

48. Tanskanen M, Uusitalo AL, Häkkinen K, et al. Aerobic fitness, energy balance, and body mass index are associated with training load assessed by activity energy expenditure. *Scand J Med Sci Sports* 2009; 19:871-878.

49. Taanila H, Suni JH, Kannus P, et al. Risk factors of acute and overuse musculoskeletal injuries among young conscripts: a population-based cohort study. *BMC Musculoskel Disord* 2015; 16:104. doi: 10.1186/s12891-015-0557-7.

50. Knapik J, Reynolds K, Harman E. Soldier load carriage: historical, physiological, biomedical, and medical aspects. *Mil Med* 2004; 169: 45–56.

51. Jones BH, Knapik JJ. Physical training and exercise-related injuries: Surveillance, research and injury prevention in military populations. *Sports Med* 1999; 27: 111–125.

52. Solberg PA, Paulsen G, Slaathaug OG, et al. Development and implementation of a new physical training concept in the Norwegian Navy Special Operations Command. *J Strength Cond Res* 2015; 29 Suppl 11:S204-210.

53. Abt JP, Oliver JM, Nagai T, et al. Block-periodized training improves physiological and tactically relevant performance in Naval Special Warfare Operators. *J Strength Cond Res* 2016; 30:39-52.

ACCEPTED MANUSCRIPT

54. Knapik JJ, Harman EA, Steelman RA, Graham BS. A systematic review of the effects of physical training on load carriage performance. *J Strength Cond Res* 2012; 26:585-597.

55. Williams A, Rayson M, Jones D. Resistance training and the enhancement of the gains in material-handling ability and physical fitness of British Army recruits during basic training. *Ergonomics* 2002; 45: 267-279.

56. O´Hara RB, Serres J, Traver J, et al. The influence of nontraditional training modalities on physical performance: review of the literature. *Aviat Space Environ Med* 2012; 83:985-990.

57. Wood P, Grant C, Toit P, et al. Effect of mixed military Training on the Physical Fitness of Male and Female Soldiers. *Mil Med* 2017; 182:e1771-1779.

58. Kraemer W, Mazzetti SA, Nindl BC, et al. Effect of resistance training on women's strength/power and occupational performances. *Med Sci Sports Exerc.* 2001; 33:1011–1025.

59. Hendrickson NR, Sharp MA, Alemany JA, et al. Combined resistance and endurance training improves physical capacity and performance on tactical occupational tasks. *Eur J Appl Physiol* 2010; 109:1197–1208.

60. Grant CC, Mongwe L, Janse van Rensburg DC, et al. The difference between exercise-induced autonomic and fitness changes measured after 12 and 20 weeks of medium-to-high intensity military training. *J Strength Cond Res* 2016; 30:2453-2459.

61. Bartlett CG, Stankorb S. Physical performance and attrition among U.S. Air Force trainees participating in the basic military training fueling initiative. *Mil Med* 2017; 182:e1603-e1609.

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Figure Legend

Figure 1. Several factors affect total training load, training adaptation and performance of an individual soldier in military environments.

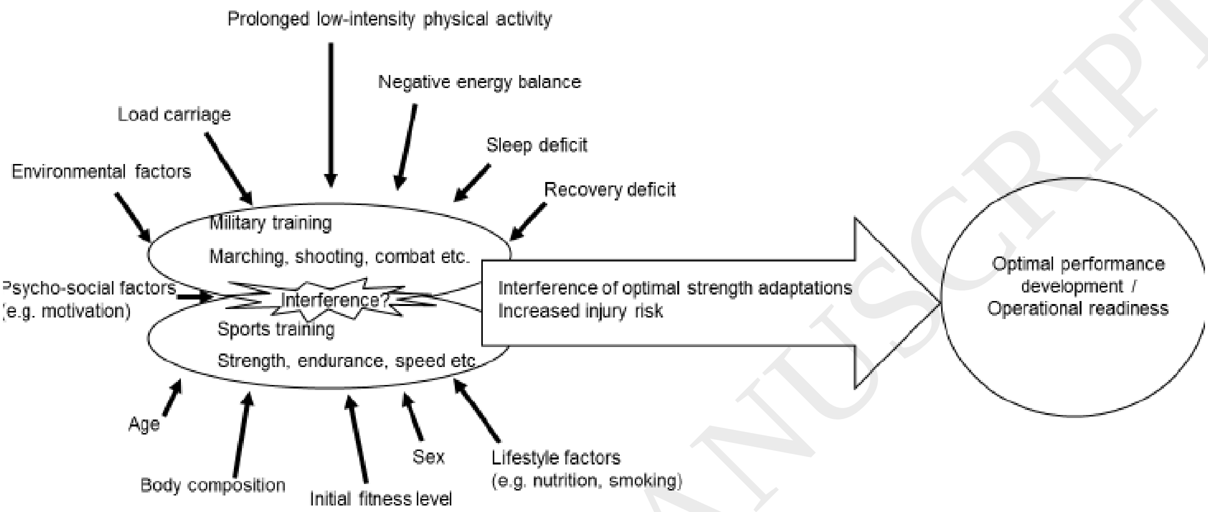

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Table 1. Findings of previous training studies in military environment

Study	Country	N	Sex (personnel group)[a]	Training program[b]	Results after training
Vantarakis et al. 2017	Greece	31	1(2)	Effect of 8-week linear periodised training program on Navy Cadets	Bench press 1RM ↑, Squat 1RM ↑ Muscle endurance ↑ (push-ups, sit-ups), 30m sprint time ↓ Navy obstacle course time ↓
Grant et al. 2016	South Africa	154	1+2(1)	Effect of 12 and 20 weeks of medium-to-high intensity military training	VO_2max ↑ during 1st 12 weeks, ↔ after 20 weeks 2.4 km run time ↓ BMI ↔
Abt et al. 2016	USA	46	1(2)	Effect of 12-week block-periodised training program in Naval Special Warfare Operators	Body fat ↓, Fat mass ↓, Body mass ↓ Aerobic capacity ↑ Upper body muscular endurance ↑ Upper and lower body power ↑ Total body muscular strength ↑
Solberg et al. 2015	Norway	22	?(2)	Assessment of novel 6-month linear (LP) vs. non-linear training program (NLP) in Navy Special Operation Forces	Both programs; abdominal strength, standing long jump ↑ LP; mobility, agility, upper body power, pull-ups, VO_2 max, muscle mass ↑, fat percent ↓ NLP; anaerobic capacity ↑, VO_2 max, upper body power ↓
Vaara et al. 2015	Finland	25	1(1)	Effect of added ST during 8-weeks of special military training	3.2 km load carriage (27 kg) time ↓ Isometric bench press ↔ Isometric leg press ↓,Abdominal strength ↑, Back extension ↓
Lester et al. 2014	USA	133	1(2)	Effect of 7-week novel physical training (NT) program compared to traditional army physical fitness training (TT)	NT improved more bench press, medicine ball put, 30m rush time, casualty recovery time than TT
Sporis et al. 2014	Croatia	124	1+2(1)	Effects of two different 5-week training programs	3.2 km run time ↓, Muscle endurance (sit-ups, push-ups, squats) ↑ No statistically significant differences between programs
Sporis et al. 2012	Croatia	25	?(2)	Effects of a training program for special operations battalion (SOB) soldiers` fitness parameters	Body mass, fat mass ↓ Muscle endurance (sit-ups, push-ups) ↔ Maximal leg extension, Bench press ↓ Aerobic and anaerobic performance ↓
Santtila et al. 2012	Finland	57	1(1)	Effects of 8 weeks basic training, followed by 8 weeks of specialised military training	VO_2 max and maximal arm and leg extension ↑ during 1st 8 weeks, ↔ after 2nd 8 weeks
Hendricks son et al. 2010	USA	56	2(3)	Effect of combined ST and ET on tactical occupational tasks	ST group => Squat ↑, Bench press ↑, Bench press throw ↑, Repeatable lift and carry ↑, 3.2 km load carriage time ↓, 3.2 km run ↔
Santtila et al. 2009	Finland	72	1(1)	Effects of 8-week basic training (BT), ET and ST on functional parameters	VO_2 max ↑ ST 12%, ET 9%, BT 13%, Body fat ↓ in all groups, leg strength ↑ ST 9,1% and ET 12.9 %
Harman et al. 2008	USA	32	1(3)	Effects or 8-week standardised army physical vs. weight-based training	Both training programs had the same effect 3.2 km and 400 m load carriage time ↓, obstacle course, sprints, casualty rescue time ↓
Kraemer et al. 2004	USA	35	1(2)	Effects of concurrent 12-week training, 4 days per week; ET, ST, upper body strength training +	All groups; push-ups ↑ (18-43%) ST + ET; sit-ups ↔ The groups that included ET; 2-mile unloaded run time ↓

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				endurance training (UB+ET) or combined (ET+ST) group	Only ET+ST and UB+ET; loaded 2-mile run time ↓ The groups that included RT exercises; leg power ↑
Williams et al. 2004	GBR	50	1(1)	10-week army basic military training including circuit or ST programmes	Both groups; loaded march performance ↑; when divided into different subgroups of 'good' and 'poor' responders by 20% and 10%, respectively.
Knapik et al. 2003	USA	2580	1+2(1)	Comparison of a standardized physical training and physical readiness training (PRT)	PRT resulted in higher fitness test pass rates and lower injury rates compared to a traditional physical training programs
Williams et al. 2002	GBR	52	1+2(1)	Normal British Army 11-week basic training with modified physical training, which consisted of added ST and a higher proportion of ET and material handling training compared to normal British Army basic training	Greater ↑ in the modified training compared with the normal training; Maximal box lift (12 vs. 2%) 3.2 km loaded march performance (9 vs. 4%) VO_2max (9 vs. 4%) Dynamic lift (16 vs. 0%) Estimated fat-free mass (4 vs. 2%) Both genders were reported separately
Kraemer et al. 2001	USA	93	2(3)	Effects of 6-month ST programmes on physical and military occupational task performances	Improvements in physical performance in relation to specificity of training ST ↑occupational performance When compared to a male control group, gender differences ↓ after ST, especially for occupational tasks

Sex: 1, male; 2, female, ?, not reported; Personnel group: (1), conscripts/recruits; (2), cadets/professional soldiers; (3), civilians. Abbreviations: 1RM, one repetition maximum; VO_2max, maximal oxygen uptake; LP, linear periodization; NLP, non-linear periodization; NT, novel training; TT, traditional training; ST, strength training; ET, endurance training; BT, basic training; UB, upper body; RT, resistance training, PRT, physical readiness training.