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Strength and Conditioning for British Soldiers

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ABSTRACT

WITH ADVANCES IN STRENGTH AND CONDITIONING, A REVIEW OF PHYSICAL TRAINING WITHIN THE BRITISH ARMY WOULD BE BENEFICIAL. MILITARY PERSONNEL EXPERIENCE HIGH INJURY RATES AND MEDICAL ATTRITION, AFFECTING MILITARY CAPABILITY. THIS MAY BE DUE TO INAPPROPRIATE PROGRESSION OF EXERCISE INTENSITY AND VOLUME, LEADING TO OVERUSE INJURIES. TO MITIGATE THIS, WE ADVISE A REDUCED RUNNING VOLUME AND GREATER EMPHASIS ON INTERVAL TRAINING, ALONG WITH MORE STRENGTH AND POWER TRAINING IN LINE WITH DEMANDS OF A MODERN MILITARY AND THE VARIOUS VOCATIONAL TASKS PERFORMED BY SOLDIERS. FOR ECOLOGICAL VALIDITY AND PRACTICAL CONSIDERATIONS, RECOMMENDATIONS ARE BASED ON LARGE GROUP TRAINING AND MINIMAL RESOURCES.

INTRODUCTION

For the British Army, musculoskeletal injuries attract a high financial cost, lost training time, an increased burden on the medical chain, and threaten operational capability. The cost of musculoskeletal injuries is expected to be in the millions. Injury during predeployment training for British Army infantry soldiers has also been shown to be significantly high, with 59% of solders having sustained one or more injuries, of which 71% involve the lower limb (65). These figures also reflect the frequency of injury during initial soldier training (noninfantry) where lower limb injuries account for the greatest number of medical discharges (81%) and referral to exercise rehabilitation (55%) (7). Detailed U.S. (29), Australian (51), Norwegian (19), and British military studies (7) have identified a number of common risk factors for injury and medical discharge during initial training courses. Frequent causative factors include low levels of aerobic fitness, poor flexibility, decreased strength, and muscle endurance, thereby explaining why these training variables are included in the British Army's Physical Development programs. Musculoskeletal overuse injuries (e.g., stress fractures) also result from a sudden increase in training volume (55,56), particularly in running (24,30), marching, and load carriage (24,25,45). In addition to physical stress, soldiers must also cope with high levels of psychological stress, including disturbed sleep patterns (including sleep deprivation), insufficient energy consumption, and inadequate recovery (16,54,66). A subsequently compromised immune system can cause infection and illness to spread fast among fellow soldiers. Regardless of the cause (illness or injury), recruits lose training days and medical and rehabilitation costs increase (55,56).

Historically, the physical training regimes and fitness testing batteries of British soldiers have advocated high levels of aerobic capacity and muscle endurance, arguing that these components of fitness should receive the greatest attention in training programs for soldiers to be successful in training and on operational deployment. This training culture, which typically favors volume over intensity, may cause and exacerbate the injury issues discussed (28). As such, and considering the many advances in sports and exercise science, a review of the current British Army physical training model is considered necessary. The aim of this review is to provide an evidence base to inform future physical development policy and any proposed changes to delivery.

THE CURRENT TRAINING PARADIGM VERSUS MODERN-DAY SOLDIERING: THE REQUIREMENT FOR STRENGTH AND POWER TRAINING

The current physical training approach for the British Army seems to

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combat; army

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mainly follow its historical tradition, involving high-volume running, marching with load, and group circuits involving callisthenic-based exercises, such as dips, heaves, press-ups and sit-ups. However, soldiering also demands explosive (power) activities, such as sprinting, changing direction at speed, jumping and landing, close quarter combat, and throwing (e.g., a grenade). In addition, many military tasks, such as manual material handling, casualty extraction, working with military vehicles, and performing tasks while carrying heavy load, requires a foundation of strength to perform. Finally, during both field training exercises and operational deployments, soldiers will carry heavy loads (Table 1) including restrictive body armor, irrespective of body mass (i.e., the load is absolute rather than relative). Each soldier carries the same load regardless of stature, dependent only on the soldier's role, leaving one to assume that stronger soldiers–for whom the load represents a smaller percentage of their 1 repetition maximum (1RM)–would demonstrate greater power and power-endurance during a given task (Table 2). Furthermore, while carrying around 50 kg, the onset of fatigue may be a consequence of the load's relative demands for muscular strength and as such, the strongest soldiers may also incur fatigue at a slower rate.

Table 1
Loads carried by British infantry (based on Antolik (2) and Orr et al. (46))

Conflict	Weight carried, kg
Crimean War	29
WW1	36
WW2	30–40
Falklands Campaign	50–68
Gulf War I	45
Gulf War II	36–80
Afghanistan	40–80

In support of this thought process, strength training decreases the relative force (% of max) applied during the loading phase of ground contact (50,61), reducing metabolic demand for the same force output and creating a motor unit reserve available for additional work (61). Along these lines, aerobic capacity can also be increased with the inclusion of strength training (62), and using magnetic resonance imaging scans, Ploutz et al. (50) showed that less muscle mass is used to lift a given load as strength increases. From this, it may be assumed that the perception (i.e., rating of perceived exertion) of workload/effort to lift that load also decreased. For example, Harrison et al. (17) found that while subjective ratings of workload and cognitive function were unchanged as a factor of training terrain (mud, sad, and tarmac), significant differences were noted when comparing the carrying of heavy load (36.94 kg; total weight including clothing) versus light load (22.77 kg). In summary, and given that load carriage is usually an occupational requirement for soldiers regardless of body size, muscle strength and power, in addition to endurance and aerobic capacity should be emphasized in the strength and conditioning program (63). Moreover, the ability of larger soldiers with greater muscle mass to carry heavier loads faster has previously been reported (47), suggesting that exercises for muscle hypertrophy should not be neglected.

Power-based movements (such as those listed above) have been highly correlated to maximum strength (r = 0.77–0.94) (3) and significant correlations have been found between the 1RM squat and a series of explosive performance tests, such as the vertical jump, broad jump, agility t test, sprint acceleration, and velocity (r = 0.80–0.89; 49). Power training is also important, as task-specific movements require high velocities to ensure they are completed as quickly as possible. Such training improves the slope of the initial portion of the force-time curve (Figure 1), targeting rate of force development (RFD), specifically within the first 200–300 milliseconds (43). This is the time frame required to complete similar movements to military tasks, although data are based on civilian populations carrying no load (1,68). Figure 1 depicts that some tasks are more dependent on force (strength training), whereas others (more time constrained) are more dependent on RFD (power training); a comprehensive training program should train both. The optimal training load for strength training is generally ≥85% 1RM (49); for power training, it is less clear. However, using the force-velocity curve (Figure 2), which represents the power output of a given task (since power is a function of force and velocity, and that they share an inverse relationship), it is evident that the power-based movements a soldier may engage in during combat are so varied that they would cover the full spectrum of the curve. As such, training must do likewise and is best achieved by using a variation of loads during power training–as our intent should always be to lift as "explosively" as possible (5) and because velocity is a function of mass. Example exercises that meet the criteria identified above are described in Table 3 and have been selected as they are circuit/field-based options with minimal equipment requirements.

AEROBIC FITNESS: RUN FASTER, NOT FURTHER

A high $\dot{V}O_2$max is likely to assist in the repetition of high-intensity tasks required for modern-day soldiering and is essential when engaged in combat operations. Also beneficial, are the effects of high aerobic fitness on injury prevention; here, one can also note the significance of relative intensity, similar for strength training as stated in the previous section. Knapik et al. (29) found that in both sexes, lower peak $\dot{V}O_2$ values increased injury risk, which is in agreement with similar studies (19,25). They suggested that soldiers with a lower aerobic capacity are likely to experience greater physiological

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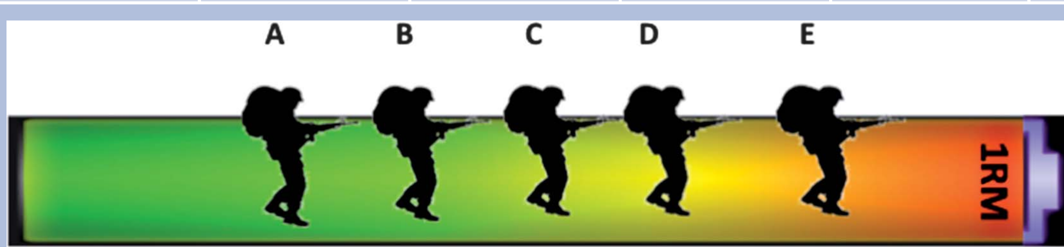
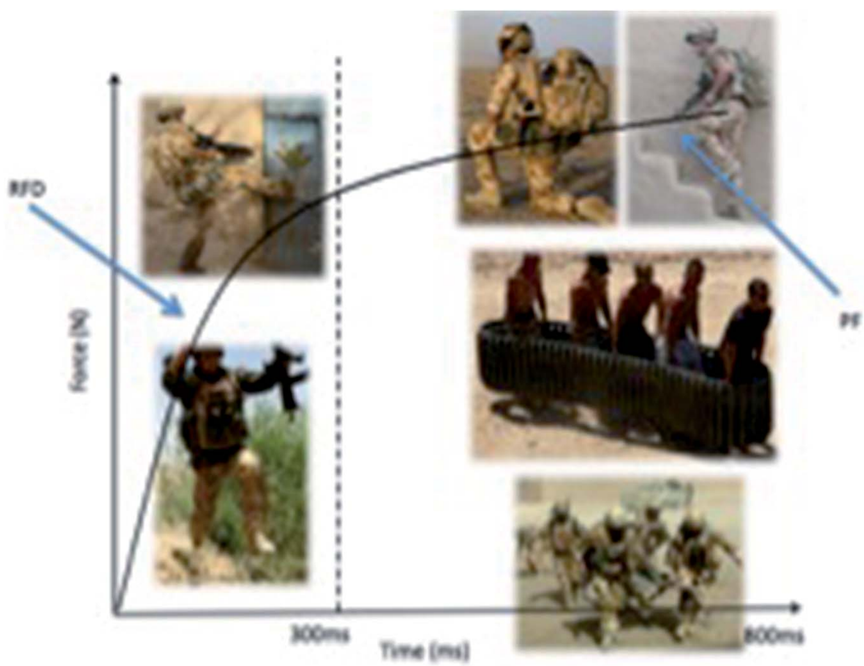
Table 2
The percentage of a soldier's 1RM in the back squat

Soldier	A	B	C	D	E
1RM squat, kg	140	120	100	80	60
Load/RM, %	36	42	50	62	83



Based on a load carriage of 50 kg, the data above represent this load as percentage of a soldier's 1RM in the back squat; the data are also represented graphically. One would assume that the less this load taxes your 1RM, the greater muscle mass and energy reserves you have for subsequent tasks.

stress during training. This is because soldiers' train in large groups, running at an absolute speed, therefore less fit soldiers will use a higher percentage of their maximal aerobic capacity compared with those with a higher aerobic capacity. They speculated that this would cause these soldiers to perceive various training tasks as more difficult, causing an earlier onset of fatigue. Fatigue may then result in changes in gait and general movement mechanics, which would cause unaccustomed musculoskeletal stress on specific body areas.



AU15 Figure 1. Force-time curve whereby the initial slope represents rate of force development (RFD) and is considered most important for movements completed within 300 milliseconds. The final height of the curve represents maximum strength/peak force (PF) and is most important for movements where time to completion is not as important. To illustrate this point, combat-specific tasks have been included, relating to one or the other.

As with load carriage, training is not always adjusted to reflect individual differences and fitness levels. All standard entry recruits undergo the same training with respect to volume, intensity, frequency, and mode, and training is undertaken in single sex platoons. Several studies undertaken in U.S. Army recruits have identified low aerobic fitness levels before the start of basic combat training as an independent risk factor for injury risk in male recruits (25,31). Similarly, Knapik et al. (31) found female recruits twice as likely to suffer an injury compared with their male counterparts. This sex difference is not found in civilian sports, where there is a similar overall injury risk (37). They suggest this is because in civilian athletics, men and women can compete separately, with different training intensities and competition rules. In the military, men and women often train and perform together and as such the relative intensity is greater for women than for men due to women's

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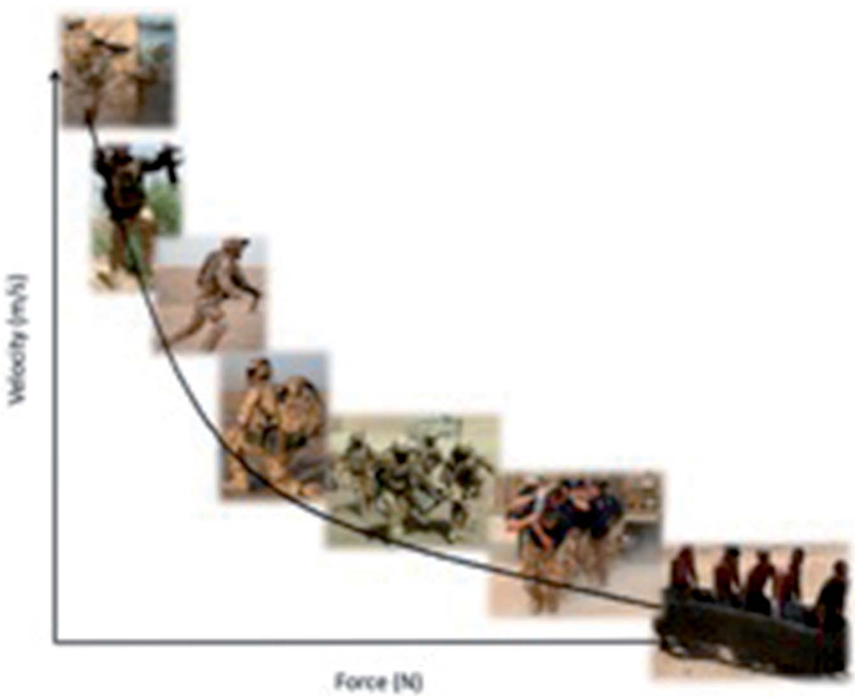

Figure 2. Force-velocity curve illustrating that force and velocity share an inverse relationship. The curve represents power output, and the point at which a task features on this curve is dependent of the mass of an object as in general, but certainly during training, our intent is always to perform with maximum explosive power.

lower average physical capacity. To substantiate their argument, they used data collected within their study to provide the following example. On a fast military road march, walking at an average speed of 4 mph, subjects would have required an energy equivalent of 14.2 $mL \cdot kg^{-1} \cdot min^{-1}$. Average $\dot{V}O_2$ peaks were 51 and 39 $mL \cdot kg^{-1} \cdot min^{-1}$ for men and women, respectively, and as such, the energy cost of this task would require 28% of the average man's peak $\dot{V}O_2$ but 36% of the average woman's peak $\dot{V}O_2$. Thus, the average woman's relative marching intensity would be greater.

In summary, a high $\dot{V}O_2max$ is important for numerous military specific tasks and injury prevention and thus this component of fitness should be trained. Where possible, recruits should be divided into groups based on fitness level to ensure the same relative intensity across all soldiers (this would negate the need for single sex training). We would speculate that very high $\dot{V}O_2max$ values (>57 $mL \cdot kg^{-1} \cdot min^{-1}$; 1.5-mile run time of <9 minutes), however, might not be necessary for undertaking soldiering tasks, and this has been shown in anaerobic predominant sports (8) and in infantry soldiers (23). The development and maintenance of high aerobic fitness may also require additional training time that would be better spent strength and power training. It may be that at this stage, additional gains in strength and power would reduce ratings of perceived exertion without improvements in aerobic fitness.

Accepting the validity of aerobic fitness, our contention relates to the means by which it is developed, typically through long slow distance running (LSDR). This should be reevaluated based on the role demands of today's soldier, as it is the views of the authors that LSDR bears little resemblance to current roles across the British Army. Furthermore, LSDR has detrimental effects to strength, RFD, and power (11), important factors within modern-day soldiering. In light of this, a more suitable alternative may be high-intensity interval training (HIIT), which is now well established in its ability to increase aerobic capacity, maintain strength and power and fundamentally, reducing training volume by up to half (15,20,67); reducing volume should also help reduce injury and attrition. The above studies suggest that higher intensities elicit greater improvements in $\dot{V}O_2max$ than lower

Table 3
Field and circuit-based exercises aimed at developing rate of force development (RFD) and strength

RFD	Strength
Med ball slam	Squats with Bergen
Med ball overhead throw	Split squats with Bergen and/or back foot raised (e.g., on a chair)
Med ball rotational throw	Nordics
Med ball chest pass	Inverted rows
Jump up to mats	Heaves (can add Bergen)
Drop jump to mats	Press-ups with Bergen

For strength, add weight as required to the Bergen (military rucksack). For RFD training, simply vary the load between sessions.

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intensities, with intervals performed at near-maximal intensity being the most effective (Table 4). In addition, longer duration runs cannot compensate for lower intensities (15). These findings are illustrated in Table 4. As described by Baker (7), intervals at 100–120% maximal aerobic speed, with a 1:1 work to rest ratio (W:R) of 15 seconds and continuing for 5–10 minutes are also considered highly effective and practically viable. Table 5 shows how to calculate interval distances from 1.5-mile run times–the British Army's aerobic performance measure as part of soldier's biannual Personal Fitness Assessment.

LOAD CARRIAGE

We also recognize that it is important to train specifically for load carriage, as this is an important component of soldiering. Much of the military research to date indicates that concurrent training (of strength and aerobic capacity) elicits greater improvements in load carriage tasks than performing physical training modalities in isolation (34,36). This supports our contention that developing both aerobic capacity and strength/power in soldiers underpins and will yield greater improvements in economy of load carriage tasks. In agreement with a review conducted by Orr et al. (46) we believe that in addition to the physical development program, this can be achieved by performing load carriage sessions between 2 and 4 times a month. More frequently may increase the risk of acute and overuse injuries and may not provide additional physiological benefit (further discussed below).

THE CONSEQUENCES OF TOO MUCH VOLUME–WHEN LESS BECOMES MORE

Like Henning et al. (21), we advise that soldiers are seen as and trained as athletes; it is important that they are fast, agile, and powerful for example. However, there is one important difference. While athletes are generally well rested allowing adaptations and regeneration to take effect, soldiers are continually exposed to various forms of stress and are often sleep deprived, in negative energy balance and exercise in extreme environments. According to Selye's general adaptation theory, stress is generic in its effect on the body and all forms of stress will contribute to reduce functional capacity. Without adequate rest (a break from the stressors), the body is unable to adapt and build a stronger defense against these stressors (supercompensation) and exhaustion will result. Chronic stress leads to the prolonged release of catecholamine's (adrenaline and noradrenaline), which causes elevated heart rate, blood pressure, and glycogenolysis (61). Plasma cortisol, the primary stress hormone, also increases which suppresses the body's immune system, exposing soldiers to infection, enhanced gluconeogenesis, and muscle wasting. Because high levels of cortisol decrease the testosterone to cortisol ratio, increased cortisol can mediate muscle anabolism resulting in a reduction in force, strength, and power output (35).

To avoid overtraining and the effects of chronic stress, periodization should be adopted allowing for variation in volume, intensity, frequency, and exercise mode in the military physical development program, thereby reducing local fatigue and enhancing recovery. Because the working day of a soldier can vary dramatically (e.g., undertaking trade and career courses, predeployment training, and field exercises), a nontraditional approach, that is, rotating strength, power, and HIIT workouts on session-to-session basis is advised. Even if training cannot be structured in this way, then simply alternating exercises between workouts with 48 hours of break between similar sessions should be of benefit. Also, the HIIT drills described above become invaluable

Table 4
Effective training systems to enhance aerobic capacity (20)

Training group	Protocol	Training intensity	Pretraining $\dot{V}O_2$max, mL·kg^{-1}·min^{-1}	Posttraining $\dot{V}O_2$max, mL·kg^{-1}·min^{-1}
Long slow distance running (LSD)	Continuous run at 70% HRmax for 45 min	Low	55.8 ± 6.6	56.8 ± 6.3
Lactate threshold running (LT)	Continuous run at lactate threshold (85% HRmax) for 24.25 min	Moderate	59.6 ± 7.6	60.8 ± 7.1
15/15 interval running	47 repetitions of 15-s intervals at 90–95% HRmax with 15-s of active resting periods at warm-up velocity, corresponding to 70% HRmax between	High	60.5 ± 5.4	64.4 ± 4.4[a]
4 × 4-min interval running	4 × 4-min interval training at 90–95% HRmax with 3 min of active resting periods at 70% HRmax between each interval	High	55.5 ± 7.4	60.4 ± 7.3[a]

[a]Significantly ($p < 0.001$) different from pre- to post-training.

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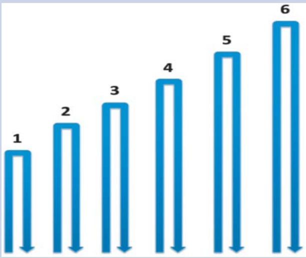
Table 5
Interval distances for high-intensity interval training calculated using a 1.5-mile run time of 10 minutes (4)

Training protocol	15-s intervals at 100–120% maximal aerobic speed (MAS)
	Work-to-rest ratio of 1:1
	Repeat over 5 min using multiple sets as appropriate
Calculating 100% MAS	v = d/t
	Where v = velocity (m/s), d = distance (m), and t = time (s)
	1.5 miles = 2,413 m; 10 min = 600 s
	v = 2,414/600 = 4 m/s
Calculating interval distance	If a soldier runs 4 m every second, then he/she will run 60 m in 15 s (4 × 15)
Calculating 120% MAS	1.2 × 100% MAS value i.e., 4 m/s × 1.2 = 4.8 m/s
Notes on shuttles and variations using agility drills	A 30-m shuttle for example, i.e., out and back and covering 60 m, probably represents 120% MAS as you must factor in the change of direction
Do not individualize too much	We do not recommend calculating lane distance for everyone in the group. Instead, simply group runners based on 30-s intervals
What does it look like?	
	For example, group 1: 12 min for 1.5 mile; therefore, they run out and back 25 m (≈120% MAS), up to group 6: 9.5 min/1.5 mile = 32 m out and back
What if you do not have the space?	Assuming only a 20-m shuttle is available. Before the run (but within the 15 s), soldiers perform an exercise, the intensity of which is dependent of how short the lane is. The exercise may be a series of tuck jumps or as simple as starting from a prone position

in reducing the volume of aerobic training (and maintaining strength and power) and that of the program as a whole. The strength and conditioning coach must then be sure to only select strength and power exercises of the highest efficacy to ensure no unnecessary wastage of energy and development of fatigue.

OVERUSE INJURIES

As subacute or chronic diseases with a multifactorial etiology that includes modifiable risk factors, some common overuse injuries are in theory preventable (58). A detailed review of injuries is beyond the scope of this text; however, a brief overview aimed at highlighting how appropriate programming can reduce injury risk is warranted. A common injury affecting army recruits is stress fractures, typically to the tibia (27,41,42). Stress fractures are a chronic or overuse injury caused by fatigue damage to the bone (42). Essentially, inadequate time for remodeling means that osteoclastic reabsorption of bone outstrips the osteoblastic formation of new bone, resulting in a weakened bone (27). A review by Jones et al. (27) reported that female soldiers performing the same prescribed physical activities as males incur stress fractures at incidences 2–10 times higher than those for men; females with a history of amenorrhea might be most at risk (14). The pathology of stress fractures is such that a reduction in running volume can reduce its occurrence, and military studies have reported that reducing running volume by approximately half reduces stress fractures by half (26,60). Furthermore, while there are many risk factors (internal and external to the soldier) that may cause a stress fracture, the initial ground reaction force and its rate of loading at landing may be

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key (42); wearing army boots (which have noncompliant soles) potentially exacerbates this. In addition to reducing the volume of LSDR and replacing it with HIIT (discussed previously), we suggest also reducing the amount of training undertaken in boots. Acclimatization to army boots perhaps requires less time than currently provided.

Other overuse injuries, such as anterior knee pain, Achilles tendonitis, ankle sprains, and back pain, are common injuries suffered by military recruits (13). Anecdotally, back pain can be avoided by enforcing good technique while exercising (especially multijoint and compound movements). Typically, exercise posture is not well coached due to large group training, which makes generic and importantly individualized coaching advice difficult. McGill (40) reports that data from studies on back pain show that poor movement pattern can lead to back disorders and that eliminating spine flexion is an effective intervention. Also, exercises now thought to be linked to back pain such as sit-ups are frequently used in military training and testing. During sit-ups (and repetitive spinal flexion in general), lumbar compression coupled with excessive disc annulus stresses will cause damage in most people (22,40,44). Exercises that isolate the abdominal region without spinal flexion/extension typically focus on strengthening the intrinsic trunk muscles, such as the transverse abdominus and internal obliques (6). Because of their attachments on the transverse processes of the spinal column, strengthening these intrinsic stabilizers will most likely provide greater levels of spinal stability, thus reducing the chances of injury (48). Example exercises include rollouts, plank variations, and antirotation exercises.

Incorporating exercises that recruit and train the muscles of the posterior chain (such as the hamstrings and gluteal group) may minimize overuse in the lumbar extensors (erector spinae), reducing the likelihood for injury and enhancing muscular firing patterns. Inclusion of such exercises may also help reduce anterior knee pain as more muscles would be recruited to perform fundamental movements, such as jumping and lifting, which may presently tax the anterior muscles (e.g., the quadriceps) to a greater extent (10,39). These muscles would also help in the tracking of the knee and thus the prevention of anterior cruciate ligament injuries and ankle sprains (38). While these muscles should of course be integral to the force generation of most movements, dysfunction seems commonplace, with a growing body of research identifying gluteus medius as one such example (9,53,59). With appropriate coaching points to address posture and technique, and exercises such as Nordics and split squats for example (Table 3), the incidence of these injuries can be reduced. Of note, overuse injuries will always be problematic in an active high-risk military population. Furthermore, some recruits join the Army with a history of injury or a genetic predisposition to a specific injury that will only develop when subjected to a biomechanical insult during training (58). Therefore, the purpose of appropriate physical conditioning and programming in the British Army is not to eradicate all injuries but to reduce injury risk to an acceptable minimum.

EVIDENCE-BASED PROGRAMMING: A FRAMEWORK FOR THE MODERN-DAY SOLDIER

Our recommendations in this article have been previously corroborated by Knapik et al. (28) and while their study addressed injury prevention, the findings are still relevant to contemporary fitness programming. The authors compared a control group conducting primarily warm-up and stretching exercises followed by calisthenics, variations on push-up and sit-up exercises, long distance group running, and some interval sprints to a multiple intervention group. The latter group looked to reduce injuries through reduced running mileage, progressive overload, different exercises performed on different days, more individualized aerobic training, and education on injury awareness and injury control techniques. Importantly, soldiers in the multiple intervention group followed a training program that allowed them to learn and gradually adapt to new exercises. Also, while the control group ran an average of 7.1 miles per week, they ran no more than 3.5 miles per week. The multiple intervention program was successful in reducing injuries (the control group had a 1.5 and 1.8 times higher injury risk in men and women, respectively) while improving physical fitness to the same extent as the control group. This group started with lower initial fitness, resulting in higher pass rates too. These findings support previous research in both military and civilian populations, which strongly suggest that as the total amount of running decreases, the incidence of injuries decreases (24,33,52,64) with little or no adverse effects on aerobic conditioning (24,64). The authors believe that it is also possible, in addition to reducing injury, to improve physical fitness scores beyond that of conventional training methods, by improving exercise selection further. Over 10 years has passed since the publication of the Knapik et al. study (28) and during this time, strength and conditioning has become an invaluable discipline of sport science with a plethora of relevant, albeit indirect research, to support this claim.

TRAINING LIMITATIONS

Recognizing the constraints of conducting military physical training is important. Most notably are the requirements to train soldiers with ratios of 1 instructor to ≥15 soldiers and thus the inability to individualize training programmes or provide adequate coaching for all. Also, such large groups make equipment availability and transportation a considerable logistical challenge; it is therefore unsurprising that circuit training and long distance running predominate. Providing sufficient intensity, or rather load, to induce significant strength gains is not always possible (especially in the stronger soldiers)—this is simply a recognized limitation. Equally important for adaptation is rest and recovery and compromises are also made here given the training demands placed on soldiers (see below).

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Table 6
Example exercise protocol for a large, field-based, group training session

Station no.	Cycle 1		Cycle 2	
	SPC	HIIT	SPC	HIIT
1	Squat back to bench	20-m sprint	Inverted row	Illinois agility run
2	Med ball slam		Med ball chest pass	
3	Nordic		Med ball over head throw	
4	Nordic		Split squat—right leg	
5	Jump up to mat		Split squat—left leg	

The group is divided in 2; concurrently, 1 group will perform the strength and power circuit (SPC), whereas the other performs high-intensity interval training (HIIT). HIIT group works in groups of 6 and continue for the length of the circuit. The SPC is 5 stations, 1 minute per station with 15-second change over time. The groups then swap over (3-minute change over). If advanced, repeat this protocol (cycle) or do another (cycle 2). Soldiers work in pairs (or more for less fit groups); for Nordics, one person will work for the full duration, the other holding the feet (soldiers swap at the next station).

Finally, military training through necessity is physically and mentally demanding. There are times when soldiers need to be exposed to high levels of fatigue, sleep deprivation, and high psychological stress during training, as it is fundamental that soldiers are prepared to function under these conditions. Our program will not necessarily help the soldiers operate under arduous and challenging conditions but soldiers must be exposed to these situations to achieve this training goal. The physical training team must simply be aware of the acute reductions in exercise performance after exposure to such stressors and where possible, tailor programs to reflect the increased demand for recovery during this time.

PRACTICAL PROGRAMMING FOR BRITISH SOLDIERS

Despite the recognized limitations identified above, the authors believe that modifications can be made to existing training programs working within these constraints, and while not always "best practice" in terms of exercise selection and programming, will still realize significant improvements. Our suggestions are described below and we have used the example of a field/circuit-based session (with limited resources), suitable for a group of >30 soldiers, thus replicating a military training lesson. The group should be divided in 2; working concurrently, one group will perform a resistance circuit, whereas the other performs HIIT (Table 6). This approach reduces the number of circuit stations and thus equipment, allowing the physical training instructor to focus on the circuit group and providing greater opportunity for coaching. Because the HIIT group will thus be effectively "unmanned," we would, in this instance, use a different training approach than described above. Soldiers in this group will work in groups of 6 and in this example perform a 20-m sprint, going one at a time (W:R = 1:5). They will continue for the length of the circuit, which will be approximately 6 minutes (5 stations, 1 minute per station with 15-second change over time). The groups will then swap over (3 minutes change over time). This protocol is illustrated in Table 6. They can do this protocol once (cycle 1), or if they are more advanced, repeat it twice or do another cycle (cycle 2). Soldiers should work in pairs and for Nordics, only one person works, the other holding the feet. Soldiers swap at the next station; hence, there are 2 Nordic stations together. To make it easier, another soldier can be added to the HIIT group (W:R now 1:6) or soldiers work in threes or fours during circuits (W:R from 1:1 to 1:2 or 1:3). This approach should help maintain intensity in less fit groups. Of note, here we recommend the principle of quality (technique) and maximal intensity of effort over quantity of repetitions. T6

CONCLUSIONS

With the advances made in sport science and strength and conditioning in particular, a review of physical training and testing within the British military is overdue. Currently, the army is experiencing high rates of injury and attrition, possibly as a result of inappropriate progression of exercise intensity and volume, which can increase the risk of overuse injuries. There is enough scientific research to justify significant changes to the program that would suggest the incidence of these injuries could be reduced. We recommend a reduction in running volume, with the remaining training program predominated by interval training. We also recommend that training programs incorporate more strength and power training in line with the demands of modern-day warfare and the increasing loads carried by soldiers. Our suggestions are based on large group training with reduced resources that should be easy to administer in any environment.

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REFERENCES

1. Aagaard P. Training-induced changes in neural function. *Exerc Sport Sci Rev* 32: 61–67, 2003. AU8
2. Antolik R. *Reducing the Burden on the Dismounted Soldier*. Capability Vision Reference Document Version 1.0. DSTL/CR36275, 2009. AU9
3. Asci A and Acikada C. Power production among different sports with similar maximum strength. *J Strength Cond Res* 21: 10–16, 2007.
4. Baker D. Recent trends in high-intensity aerobic training for field sports. *Prof Strength Cond* 22: 3–8, 2011. AU10
5. Behm D and Sale D. Intended rather than actual movement velocity determines velocity specific training response. *J Appl Physiol (1985)* 74: 359–368, 1993.
6. Beim G, Giraldo J, Pincivero D, Borror M, and Fu F. Abdominal strengthening exercises: A comparative EMG study. *J Sport Rehabil* 6: 11–20, 1997.
7. Blacker S, Wilkinson D, Bilzon J, and Rayson M. Risk factors for training injuries among British army recruits. *Mil Med* 173: 278–286, 2008.
8. Carey D, Drake M, Pliego G, and Raymond R. Do hockey players need aerobic fitness? Relation between VO2max and fatigue during high-intensity intermittent ice skating. *J Strength Cond Res* 23: 963–966, 2007.
9. Crossley K, Zhang WJ, Schache A, Bryant A, and Cown S. Performance on the single leg squat task indicates hip abductor muscle function. *Am J Sports Med* 39: 866–873, 2011.
10. Earl J and Hoch A. A proximal strengthening program improves pain, function, and biomechanics in women with patellofemoral pain syndrome. *Am J Sports Med* 39: 154–163, 2010.
11. Elliott M, Wagner P, and Chiu L. Power athletes and distance training. Physiological and biomechanical rationale for change. *Sports Med* 37: 47–57, 2008.
12. Esfarjani F and Laursen P. Manipulating high-intensity interval training: Effects on VO2max, the lactate threshold and 3000 m running performance in moderately trained males. *J Sci Med Sport* 10: 27–35, 2007.
13. Finestone A, Milgrom C, Evans R, Yanovich R, Constantini N, and Moran D. Overuse injuries in female infantry recruits during low-intensity basic training. *Med Sci Sports Exerc* 40: S630–S635, 2008.
14. Friedl K, Nuovo J, and Patience T. Factors associated with stress fracture in young army women: Indications for further research. *Mil Med* 157: 334–338, 1992.
15. Gormley S, Swain D, High R, Spina R, Dowling E, and Kotipalli U. Effect of intensity of aerobic training on VO2max. *Med Sci Sports Exerc* 40: 1336–1343, 2008.
16. Greeves J. *Nutrition: Energy Deficit Impairs Physical Performance and Immune Health During Short-Term Arduous Training*. 2013. DGAMS Annual Report on the Health of the Army, 2012–2013.
17. Harrison C, Krausman A, Harper W, Faughn J, and Sharp M. *Cognitive and Physiological Performance of Soldiers While They Carry Loads Over Various Terrains*. Army research lab aberdeen proving ground md, 1999.
18. Heir T and Eide G. Age, body composition, aerobic fitness and health condition as risk factors for musculoskeletal injuries in conscripts. *Scand J Med Sci Sports* 6: 222–227, 1996.
19. Heir T and Eide G. Injury proneness in infantry conscripts undergoing a physical training programme: Smokeless tobacco use, higher age, and low levels of physical fitness are risk factors. *Scand J Med Sci Sports* 7: 304–311, 1997.
20. Helgerud J, Hoydal K, Wang E, Karlsen T, Berg P, and Bjerkaas M. Aerobic high-intensity intervals improve VO2max more than moderate training. *Med Sci Sport Exerc* 39: 665–671, 2007.
21. Henning P, Khamoui A, and Brown L. Preparatory strength and endurance training for US army basic combat training. *Strength Cond J* 33: 48–57, 2011.
22. Hodges P and Richardson C. Inefficient muscular stabilization of the lumbar spine associated with low back pain. *Spine* 21: 2640–2650, 1996.
23. Hoffman J. The relationship between aerobic fitness and recovery from high-intensity exercise in infantry soldiers. *Mil Med* 162: 484–488, 1997.
24. Jones B, Cowan D, and Knapik J. Exercise, training and injuries. *Sports Med* 18: 202–214, 1994.
25. Jones B, Cowan D, Tomlinson J, Robinson J, Polly D, and Frykman P. Epidemiology of injuries associated with physical training among young men in the army. *Med Sci Sports Exerc* 25: 97–203, 1993. AU11
26. Jones B, Shaffer R, and Snedecor M. Injuries treated in out-patient clinics: Surveys and research data. *Mil Med* 164: 86–89, 1999.
27. Jones B, Thacker S, Gilchrist J, Kimsey D, and Sosin D. Prevention of lower extremity stress fractures in athletes and soldiers: A systematic review. *Epidemiol Rev* 24: 228–247, 2002.
28. Knapik J, Bullock S, Canada S, Toney E, Wells J, and Hoedebecke E. Influence of an injury reduction program on injury and fitness outcomes among soldiers. *Inj Prev* 10: 37–42, 2004.
29. Knapik J, Canham-Chervak M, Hauret K, Hoedebecke E, Laurin M, and Cuthie J. Discharges during U.S. army basic training: Injury rates and risk factors. *Mil Med* 166: 641–647, 2001.
30. Knapik J, Scott S, Sharp M, Hauret K, Darakjy S, and Rieger W. The basis for prescribed ability group run speeds and distances in U.S. army basic combat training. *Mil Med* 171: 669–677, 2006. AU12

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31. Knapik J, Sharp M, Canham-Chervak M, Hauret K, Patton J, and Jones B. Risk factors for training related injuries among men and women in basic combat training. *Med Sci Sports Exerc* 33: 946–954, 2001.
32. Koplan J, Powell K, and Sikes R. An epidemiologic study of the benefits and risks of running. *JAMA* 248: 3118–3121, 1982.
33. Koplan J, Rothenberg R, and Jones E. The natural history of exercise: A 10-yr follow-up of a cohort of runners. *Med Sci Sports Exerc* 27: 1180–1184, 1995.
34. Kraemer W, Mazzetti S, Nindl B, Gotshalk L, Volek J, and Bush J. Effect of resistance training on women's strength/power and occupational performance. *Med Sci Sports Exerc* 33: 1011–1025, 2001.
35. Kraemer W and Ratamess N. Hormonal responses and adaptations to resistance exercise and training. *Sports Med* 35: 339–361, 2005.
36. Kraemer W, Vescovi J, Volek J, Nindl B, Newton R, and Patton J. Effects of concurrent resistance and aerobic training on load-bearing performance and the army physical fitness test. *Mil Med* 169: 994–999, 2004.
37. Lanese R, Strauss R, Leizman D, and Rotondi A. Injury and disability in matched men's and women's intercollegiate sports. *Am J Public Health* 80: 1459–1462, 1990.
38. McCurdy K and Connor C. Unilateral support resistance training incorporating the hip and knee. *Strength Cond J* 25: 45–51, 2003.
39. McCurdy K, O'Kelley E, Kutz M, Langford G, Ernest J, and Torres M. Comparison of lower extremity EMG between the 2-leg squat and modified single-leg squat in female athletes. *J Sport Rehabil* 19: 57–70, 2010.
40. McGill S. Core training: Evidence translating to better performance and injury prevention. *Strength Cond J* 32: 33–46, 2010.
41. Milgrom C, Giladi M, Stein M, and Kashtan H. Stress fractures in military recruits. A prospective study showing an unusually high incidence. *J Bone Joint Surg* 67: 732–735, 1985.
42. Milner C. Gait biomechanics and tibial stress fracture in runners. ISBS-Conference Proceedings Archive, 2009. AU13
43. Newton R and Kraemer W. Developing explosive muscular power: Implications for a mixed methods training strategy. *Strength Cond J* 16: 20–31, 1994.
44. Norris C. Abdominal muscle training in sport. *Br J Sports Med* 7: 19–27, 1993.
45. O'Connor F, Howard T, Fieseler C, and Nirschl R. Managing overuse injuries: A systematic approach. *Phys Sports Med* 25: 88–113, 1997.
46. Orr R, Pope R, Johnston V, and Coyle J. Load carriage: Minimising soldier injuries through physical conditioning–A narrative review. 1997. Available at: http://works.bepress.com/rob_orr/9/.
47. Pandorf C, Harman E, Frykman P, Patton J, Mello R, and Nindl B. Correlates of load carriage and obstacle course performance among women. *Work* 18: 179–189, 2002.
48. Panjabi M. The stabilizing system of the spine. Part I: Function, dysfunction, adaptation and enhancement. *J Spinal Disord* 5: 383–389, 1992.
49. Peterson M, Alvar B, and Rhea M. The contribution of maximal force production to explosive movement among young collegiate athletes. *J Strength Cond Res* 20: 867–873, 2006.
50. Ploutz L, Tesch P, Biro R, and Dudley G. Effect of resistance training on muscle use during exercise. *J Appl Physiol (1985)* 76: 1675–1681, 1994.
51. Pope R, Herbert R, Kirwan J, and Graham B. Predicting attrition in basic military training. *Mil Med* 164: 710–714, 1999.
52. Powell K, Kohl H, and Capersen C. An epidemiological perspective on the causes of running injuries. *Phys Sportsmed* 14: 100–114, 1986.
53. Presswood L, Cronin J, Keogh J, and Whatman C. Gluteus medius: Applied anatomy, dysfunction, assessment, and progressive strengthening. *Strength Cond J* 30: 41–53, 2008.
54. Richmond V, Wilkinson D, Rayson M, Wright A, and Izard R. Energy balance and physical demands during an 8-week arduous military training course. *Mil Med* 179: 421–427, 2014.
55. Ross J. A review of lower limb overuse injuries during basic military training. Part 1: Types of overuse injuries. *Mil Med* 158: 410–415, 1993.
56. Ross J. A review of lower limb overuse injuries during basic military training. Part 2: Prevention of overuse injuries. *Mil Med* 158: 415–420, 1993.
57. Rudzki S and Cunningham M. The effect of modified physical training program in reducing injury and medical discharge rates in Australian army recruits. *Mil Med* 164: 648–652, 1999.
58. Scher D, Belmont P, Mountcastle S, and Owens B. The incidence of primary hip osteoarthritis in active duty US military servicemembers. *Arthritis Rheum* 61: 468–475, 2009.
59. Schmitz R, Riemann B, and Thompson T. Gluteus medius activity during isometric closed chain hip rotation. *J Sport Rehabil* 11: 179–188, 2002. AU14
60. Shaffer R and Almeida S. Musculoskeletal injury project: Naval Health Research Center. 43rd Annual Meeting of the American College of Sports Medicine. Cincinnati, OH, 1996: 24. pp. 228–247.
61. Stone M, Stone M, and Sands W. *Principles and Practice or Resistance Training*. Human Kinetics, 2007.
62. Storen O, Helgerud J, Stoa E, and Hoff J. Maximal strength training improves running economy in distance runners. *Med Sci Sports Exerc* 40: 1087–1092, 2008.
63. Szivak T, Kraemer W, Nindl B, Gotshalk L, Volek J, and Gomez A. Relationships of physical performance tests to military-relevant tasks in women. *US Army Med Dep J* 2: 20–26, 2013.
64. Trank T, Ryman D, and Minagawa R. Running mileage, movement mileage, and fitness in male US Navy recruits. *Med Sci Sports Exerc* 33: 1033–1038, 2001.
65. Wilkinson D, Blacker S, Richmond V, Horner F, Rayson P, and Spiess A. Injuries and injury risk factors among British army infantry soldiers during pre-deployment training. *Inj Prev* 17: 381–387, 2011.
66. Wilkinson D, Rayson M, and Bilzon J. A physical demands analysis of the 24-week British Army Parachute Regiment recruit training syllabus. *Ergonomics* 51: 649–662, 2008.
67. Wisloff U, Stoylen A, and Loennechen J. Superior cardiovascular effect of aerobic interval training versus moderate continuous training in heart failure patients. *Circulation* 115: 3086–3094, 2007.
68. Zatsiorsky V. Biomechanics of strength and strength training. In: *Strength and Power in Sport. Volume 2*. Komi P, ed. Oxford, United Kingdom: Blackwell Science, 2003. pp. 114–133.

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