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REVIEW

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Physical training considerations for optimizing performance in essential military tasks

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ABSTRACT
Physically demanding essential military tasks include load carriage, manual material handling and casualty evacuation. This narrative review characterizes the main physical attributes related to performance of these occupational tasks and reviews physical training intervention studies in military settings to improve performance in these military tasks. Load carriage performance requires both aerobic and neuromuscular fitness with greater emphasis on maximal strength and absolute maximal oxygen uptake, especially when carrying heavier loads. In manual material handling, maximal strength and power are strongly associated with discrete lifting, while muscular strength, muscular endurance and aerobic fitness are also associated with repetitive lifting performance. Maximal strength including grip strength, muscular endurance, absolute maximal oxygen uptake and anaerobic capacity are associated with casualty evacuation performance. The results of the present review particularly emphasize the role of muscular fitness in successful performance of the reviewed military occupational tasks. Training intervention studies indicate that load carriage performance can be effectively improved by combining strength, aerobic and specific load carriage training. Improvement in maximal lifting capacity can be achieved by strength training or combined strength and aerobic training, while strength and aerobic training alone, or their combination are effective in improving repetitive lifting, and carry tasks. Only a few studies are available for casualty evacuation and the results are inconclusive but may indicate benefits of strength or combined training. Moreover, emphasis on lower volume but higher intensity in combined training may be a feasible and effective mode to improve military occupational performance in recruits and active-duty soldiers.

KEYWORDS
Environmental physiology; strength; endurance; exercise; fitness

Introduction

Physical fitness is a fundamental underpinning capability for soldiers. Despite considerable technological advances in materials and equipment, the burden of external load on soldiers has not decreased, rather it has progressively increased over time (Knapik, Reynolds, & Harman, 2004), with operational loads potentially exceeding 60 kg (Dean, 2004; Nindl et al., 2013). Although operational load carriage tasks (e.g. patrolling and fire and move) are an enduring requirement, soldiers also have considerable exposure to manual material handling tasks, an activity classification that is ubiquitous within military service (Carstairs et al., 2018; Lester et al., 2010). In addition, soldiers may also be required to undertake casualty evacuation tasks, with high aerobic and neuromuscular demands (Larsson, Dencker, Olsson, & Bremander, 2020). Hence, an a priori understanding of the physical requirements for the essential military tasks of load carriage, manual material handling and casualty evacuation is essential when considering suitability of preparatory and maintenance training regimens for recruits and soldiers.

Tolerance to the physical stressors imposed by manual material handling, load carriage and casualty evacuation requires the multi-faceted development across a spectrum of aerobic, muscular endurance, muscular strength, and power fitness domains (Chassé, Tingelstad, Needham-Beck, & Reilly, 2019; Drain, Billing,

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Neesham-Smith, & Aisbett, 2016; Nindl et al., 2015; Pihlainen, Santtila, Häkkinen, Lindholm, & Kyröläinen, 2014). Military operations introduce complexity, constraints and demands that may impose additional physical burden, diminishing functional capacity and challenging the physiological reserves of the soldier (Nindl et al., 2013). For example, sleep restriction, energy deficit, and heat and cold exposure are routinely encountered stressors that impair soldier performance (Castellani et al., 2003; Nindl et al., 2006). However, improved physiological resilience can be achieved through targeted physical training that improves physical fitness and the capacity to meet the unique demands of military occupation (Nindl et al., 2018). Therefore, one of the key elements for each soldier is adherence to an appropriate training programme to effectively maximize physiological capacity to meet occupational demands while retaining sufficient residual physical capacity to maintain operational effectiveness.

Recent evidence has demonstrated that the concurrent application of resistance and aerobic training is the optimal training structure to facilitate adaptation to meet the physical demands of military service and reduce musculoskeletal injury risk (Burley, Drain, Sampson, Nindl, & Groeller, 2020; Kyröläinen, Pihlainen, Vaara, Ojanen, & Santtila, 2018). The current review has therefore focused upon, exploring the specific and unique physical attributes that must be developed to improve tolerance to essential military tasks. Given these physical attributes and the recommendations of Kyröläinen et al. (2018), the main purpose of this review was to ask how should military training regimens be concurrently applied to adequately develop these capacities, yet retain practical utility for implementation within a military setting.

Materials and methods

Although the present study represents a narrative review we included elements from a systematic review search strategy. A literature search was conducted in Pubmed for both original studies and review articles. Inclusion criteria were as follows: (1) training intervention study lasting at least 4 weeks (2) the outcome variable either load carriage, manual material handling or casualty evacuation performance (3) participants were adults (≥18 years) (4) and the study was published in a peer-reviewed journal. Firstly, the associations of physical fitness and body composition attributes with the most common military tasks: load-carriage, manual material handling and casualty evacuation was searched using keywords: soldier, military, load-carriage, manual material handling and casualty evacuation. Secondly, the literature search for the effects of physical training on task-specific military performance including at least one of the following military tasks, load-carriage, manual material handling and casualty evacuation as outcome measures was performed. Regarding the effects of physical training on load carriage, we report the results of a previous systematic review by Knapik, Harman, Steelman, and Graham (2012) and extend the findings from the studies published thereafter. In addition to literature searches, authors provided references from their own archives after the literature search if appropriate articles appeared to futher extend the topics of the present review.

Physical fitness requirements in military occupational performance

Load carriage

The most essential and common combat-related physically demanding task for soldiers is load carriage (Dean, 2004; Knapik et al., 2004). Independent of specific duties for a soldier or for a given military environment, soldiers often carry combat gear and sustainment stores (Drain et al., 2016) with loads varying from 20 kg up to 70 kg for an emergency march load (Dean, 2004; Nindl et al., 2013). Load carriage impacts physical and physiological demands in multiple ways. These include the magnitude of carried mass, its distribution, the terrain (gradient, surface) and movement speed, all of which can increase cardiorespiratory, metabolic and neuromuscular demands as well as thermal burden (Blacker, Fallowfield, Bilzon, & Willems, 2013; Fallowfield, Blacker, Willems, Davey, & Layden, 2012; Knapik et al., 2004; Taylor, Peoples, & Petersen, 2016; Teitlebaum & Goldman, 1972).

Previous studies have reported associations between load carriage performance and aerobic and muscular fitness, as well as body composition (e.g. Fallowfield et al., 2012; Lyons, Allsopp, & Bilzon, 2005; Rayson, Holliman, & Belyavin, 2000; Terho, Vaara, & Kyröläinen, 2018). Maximal absolute oxygen uptake ($L \cdot min^{-1}$) has been shown to moderately correlate with load carriage performance with 20–45 kg (Fallowfield et al., 2012; Lyons et al., 2005; Rayson et al., 2000; Terho et al., 2018), while relative maximal oxygen uptake ($mL \cdot kg^{-1} \cdot min^{-1}$) is not associated with performance in this external load range (Fallowfield et al., 2012; Terho et al., 2018). However, relative maximal oxygen uptake ($mL \cdot kg^{-1} \cdot min^{-1}$) has been correlated with load carriage performance with lighter loads (15–25 kg) (Lyons et al., 2005; Rayson et al., 2000). Among muscular fitness variables, Rayson et al. (2000) demonstrated a correlation between load carriage (15–25 kg) and maximal strength and muscular endurance. In addition, Terho et al. (2018) reported that upper body maximal strength was strongly and positively correlated with moderate (29 kg) and heavier (45 kg) load carriage performance whereas lower body strength, standing long jump and muscular endurance was not correlated with performance with either mass. Among body composition variables, body mass and lean body mass have been shown to correlate with load carriage performance with loads varying of 15–45 kg (Fallowfield et al., 2012; Rayson et al., 2000; Terho et al., 2018).

Manual material handling

Manual material handling is a routinely performed and an essential task in the military. A recent review identified 583 physically demanding tasks across 57 employment categories within the Australian Army, of which 458 (∼79%) were classified as manual material handling tasks (Carstairs et al., 2018). Manual handling tasks can include lifting, digging, carrying, pushing, pulling, and their combinations (Carstairs et al., 2018). These tasks can be discrete, continuous or repetitive in their nature (Savage, Best, Carstairs, Ham, & Doyle, 2014). Manual material handling tasks should ideally be performed at sub-maximal level to limit fatigue and reduce the risk of injury (Savage, Best, Carstairs, & Ham, 2012). Furthermore, recent evidence has shown that manual material handling was associated with the highest injury risk in soldiers during deployment (Roy, Knapik, Ritland, Murphy, & Sharp, 2012).

Among physical fitness variables, maximal strength and power have consistently shown a strong correlation with discrete lifts, whereas weaker associations were reported with muscular endurance (Hauschild et al., 2017; Hydren, Borges, & Sharp, 2017; Rayson et al., 2000). Absolute maximal oxygen uptake (L·min^{-1}) and relative maximal oxygen uptake (mL·kg^{-1}·min^{-1}) have been observed to have a moderate and weak correlation, respectively (Hauschild et al., 2017; Hydren et al., 2017). Additionally, body mass and in particular lean body mass has been shown to have a strong correlation with maximal lift capacity (Hydren et al., 2017; Rayson et al., 2000). For example, Hydren et al. (2017) concluded in their meta-analysis that lean body mass had the strongest association with discrete lifts, explaining 69% of the variance in maximal lifting capacity, whereas other anthropometric variables explained only 24–54%.

Lifts, however, are commonly performed repetitively rather than only as a single maximal lift. Maximal strength, power and aerobic fitness have shown a moderate to strong association with repetitive lift performance (Hauschild et al., 2017; Rayson et al., 2000). Such correlations are consistent with the significant increase in oxygen uptake observed with lifting of an external load (Beck et al., 2016). For example, repetitive artillery field preparation tasks elicited 40% of maximal oxygen uptake and 50% of peak heart rate in recruits (Pihlainen et al., 2014). In contrast, and somewhat counter-intuitively, muscular endurance has been shown to have a weak to moderate correlation with repetitive lifting, lift and carry, stretcher carry, crawling and digging tasks (Hauschild et al., 2017). Similar to associations observed within maximal lift capacity, stature and lean body mass have positive correlations with the performance of repetitive lifting tasks (Rayson et al., 2000).

Casualty evacuation

Casualty evacuation is a military task that every soldier may reasonably be required to undertake and therefore soldiers should be capable of performing. Casualty evacuation can involve separate or combined actions including carrying, lifting and dragging. Although, casualty evacuations are often performed with more than one person, there may be the requirement to perform this task individually, e.g. during frontline operations. This significantly increases the physical demands for the individual soldier performing the task. Individual casualty evacuation tests have typically involved dragging a 61–80 kg mannequin over a 50–200 m course (Harman et al., 2008; Hendrickson et al., 2010; Lester et al., 2014; Poser et al., 2019; Solberg et al., 2015), however, the distance evacuated and the mass of the evacuated soldier can be significantly higher in operational combat scenarios. Rescue evacuations are associated with a significant cardiovascular strain, with 92–98% of maximal heart rate (Myhre et al., 1997; Williford, Duey, Olson, Howard, & Wang, 1999), and 68% of heart rate reserve (Chassé et al., 2019) during a 7 min casualty evacuation reported.

Among physical fitness tests, maximal strength and grip strength, muscular endurance, absolute maximal oxygen uptake (L·min^{-1}) and anaerobic capacity have shown weak to moderate correlations with casualty evacuation tests ranging from 15 to 50 m in distance to longer evacuation scenarios (Angeltveit, Paulsen, Solberg, & Raastad, 2016; Arvey, Landon, Nutting, & Maxwell, 1992; Michaelides, Parpa, Henry, Thompson, & Brown, 2011; Poser et al., 2019; Rhea, Alvar, & Gray, 2004). Among anthropometrics, stature, lean body mass (Angeltveit et al., 2016) and body mass (Angeltveit et al., 2016; Poser et al., 2019) have shown to moderately correlate with a simulated casualty evacuation test (40–50 m). Furthermore, lean body mass to dead mass (fat mass + external load) ratio and maximal strength together predicted the variance in prolonged (~7 min) casualty evacuation performance by 70% (Chassé et al., 2019). Casualty evacuation involving a stretcher carry, upper body muscular endurance and muscle mass have been associated with the carry performance to volitional exhaustion (Knapik, Harper, & Crowell, 1999).

The effect of physical training on military occupational performance

Load carriage

Knapik et al. (2012) demonstrated in a systematic review consisting of 10 original physical training intervention studies that the greatest improvement in load carriage performance was achieved with a training programme consisting of whole-body strength and aerobic training combined with load carriage training (Summary effect size, SES: 1.7 SD units). Periodised whole-body strength and aerobic training programmes in the absence of load carriage training yeilded the next greatest improvement in load carriage performance (SES: 1.2), followed by field based training which included a wide variety of physical training activities such as sandbag-lifts, plyometrics, agility, hill running, aerobic training and manual material handling (SES: 1.1). Furthermore, combined strength and aerobic training lasting at least four weeks for three training sessions per week improved load carriage performance (SES: >0.8), while strength training alone was nearly as effective (SES: 0.75). The lowest effect size was reported for aerobic training alone (SES: 0.3).

Original studies conducted subsequent to this review have demonstrated mixed but potentially coherent results. Burley et al. (2020) reported in recruits that a physical training regimen that focused on combined strength and aerobic training with an emphasis on low volume high-intensity training was more effective in improving load-carriage performance (3.2 km, 20 kg) compared with a control group, who undertook standard military physical training consisting of running, circuit training and load carriage during 12 weeks of basic training. Other training intervention studies in recruits have demonstrated no benefit of additional strength and/or aerobic training on load carriage performance (3.0–3.2 km, 14.2–27.0 kg) beyond the standard physical training regimen (Santtila, Häkkinen, Kraemer, & Kyröläinen, 2010; Vaara, Kokko, Isoranta, & Kyröläinen, 2015) (Table 1). The addition of two resistance training sessions per week with aerobic and military endurance enhancement training (load carriage, loaded carry, fire and movement) improved performance of 5-km loaded (45 kg) march, a 2.4 km loaded run (15 kg) and fire and movement (15 kg) to a greater extent than standardized aerobic and military endurance enhancement training alone in Australian soldiers (Heilbronn, Doma, Gormann, Schumann, & Sinclair, 2020) (Table 1).

Several recent civilian studies provide further insight into the effect of physical training regimen on load carriage performance. A 24-week periodized combined strength and aerobic training intervention (1.5 h training 5 times per week) demonstrated improvements in 3.2 km load carriage (34 kg) in untrained civilian women (Nindl et al., 2017) (Table 1), while Wills et al. reported in male (Wills, Saxby, Glassbrook, & Doyle, 2019) and female civilians (Wills, Drain, Fuller, & Doyle, 2020) that 10 weeks of whole-body strength training (3 sessions/week) combined with separate progressive load carriage training (2 sessions/week) induced changes in responses to a 5-km submaximal load carriage task (23 kg). A lower rate of perceived exertion (RPE) during load carriage (Wills et al., 2019) was observed in men and a lower oxygen uptake was observed in women demonstrating improved efficiency (Wills et al., 2020).

Collectively, these results demonstrate the benefits of combined strength and aerobic training on load carriage performance in soldiers, when compared with traditional military physical training which is largely comprised of higher volume moderate intensity activities such as continuous running, circuits and prolonged load carriage. Furthermore, studies in recruits and active duty soldiers have shown that lower running and marching volumes are associated with reduced injury incidence and/or equivalent physical performance changes when compared with higher volume groups (Roos et al., 2015; Schuh-Renner et al., 2017). Recruits and active-duty soldiers alike undertake numerous physically and physiologically demanding activities within and outside of physical training, consequently the total training load must be assessed, along with recovery opportunities, when prescribing physical training regimen.

Manual material handling

Burley et al. (2020) reported in recruits completing 12 weeks of basic training greater improvement in maximal lifting capacity for combined strength and low volume high intensity aerobic training compared to standard military physical training consisting of running, circuit training and load carriage exercises. Williams, Rayson, and Jones (2002) investigated the effects of modified physical training during an 11-week recruit

Table 1. Physical training intervention studies on load carriage performance.

Study (study sample)	Training model: Duration	Group	Mode	Session duration	Frequency	Intensity	Other physical training details	Load carriage performance
Harman et al. (2008) (32 civilian males)	8 weeks	Resistance training group (RT)	Resistance training, runs, sprints, agility, load carriage	90 min	5 days/ week	To the best of their ability, load carriage at 6.4 km/h	Pace 90 sec/set progressive load carraige (0–33 kg), sprints varied 100–800 m	**3.2 km load carriage test (27 kg)** RT: decreased time (−15%) CON: decreased time (−14%) No differences in imiprovements between groups
		Army standardized physical training group (CON)	Calisthenics, drills, sprints, distance running, stretching	90 min	5 days/ week	To the best of their ability	Standardized sets and repetitions in calisthenics, running pace adjusted to fitness level	
Santtila et al. (2010) (72 conscript males)	8 weeks	Basic training (NT), $n = 24$	Approximately 44 (ST), 51 (ET), 33 h (NT) total over the course of basic training	Sport-related physical training in basic training period included running, Nordic walking, walking, cycling, RT, ball games, orienteering, and others			The basic training included combat simulations and marching with a load of 15–25 kg, markmanship training, material handling, general military and theoretical education, skill training for all groups	**3 km loaded (14.2 kg) running test** NT: decreased time (−10.2%) ST: decreased time (−12.4%) ET: decreased time (−11.6%) No differences between the groups
		Basic training + strength training (ST), $n = 24$		60–90 min/ day	3 days/ week	Linear periodized training with progressive loads from 30 to 80% (−100%) RM		
		Basic Training + Endurance Training (ET), $n = 24$		60–90 min/ day	3 days/ week	50–70% Max HR		
Vaara et al. (2015) (25 conscript males)	8 weeks	Experimental (EXP) group with additional strength training, $n = 13$	Resistance training, included hypertrophy, strength, and power blocks; completed alongside the standard special military training	60 min/day	2 days/ week	70–90% 1-RM	EXP group exercised 2 additional strength training and underwent the standardized special military training including battlefield training (170 h), marching (10 h) and physical training (15 h)	**3.2 km load carriage test (27 kg)** EXP: decreased time (−9.9%) CON: decreased time (−9.4%) No differences between the groups
		Control group (CON) group without additional strength training, $n = 12$	The standard special military training	Physical training (15 h) in special military training period included ball games, running, muscular fitness training and some exercises of free choice			Control group underwent the standardized special military training including battlefield training (170 h), marching (10 h) and physical training (15 h)	
Nindl et al. (2017) (civilians: 18 men, 40 women)	24 weeks	Traing group (only women) Control group at baseline (only men)	Resistance, aerobic, and load carriage training	Limited at 90 min/ day	Limited at 5 days/ week	RT: load prescribed so that participants could complete repetitions, but not additional repetitions: Running: physically demanding pace for an individual Load carriage: 6.4 km/h with progressive load	Weeks 1–18: RT 4 days/week and Running 2 days/week Weeks 19–24: RT 2 days/week with double volume. After week 14 load decreased and reps increased + possibility to include interval running at faster speeds. 8 km progressive load carriage with 11–34 kg by the end of training	**3.2 km load carriage (34 kg)**: decreased time (pre vs. mid: −18.5%) (pre vs. post: −23.8%)
Heilbronn et al. (2020) (49 male active duty soldiers)	9 weeks	Periodized group (PRD), $n = 18$	Resistance training, aerobic, military conditioning, and recovery sessions	90 min	5 days/ week	72–100% 1-RM	1 Aerobic session, 1 Military specific conditioning session, 1 Recovery session, 2 RT and HITT except CON group, whom did not undertake the resistance training. Loaded march	**2.4 km loaded run (15 kg)**: No changes **5.0 km loaded march (45 kg)**: PRD: decreased time
		Non-periodized group (NPRD), $n = 19$				85% 1-RM		

(*Continued*)

Table 1. Continued.

Study (study sample)	Training model						Other physical training details	Load carriage performance
	Duration	Group	Mode	Session duration	Frequency	Intensity		
		Control group with no resistance training (CON), $n = 12$	No RT			To the best of their ability	progressed to 12 km with 45 kg followed by a loaded run that progressed to 1 km with 23 kg	(−12.4%) NPRD: decreased time (−11.8%) CON: no change
Wills et al. (2019) (15 civilian males)	10 weeks	Combined resistance training and load-carriage training group	Progressive resistance training and load-carriage training	–	5 days/ week	Load carriage progressed from 0 to 25 kg load with distance from 3 to 6 km	Progressive load-carriage training (2 sessions/week) and resistance training (3 session/week). Resistance training included mainly 3–5 × 5–10 reps.	**5 km load carriage (23 kg, 5.5 km·h)** Decreased submaximal RPE No change in sub maximal heart rate
Wills et al. (2020) (11 civilian females)	10 weeks	Combined resistance training and load-carriage training group	Progressive resistance training and load-carriage training	–	5 days/ week	Load carriage progressed from 0 to 25 kg load with distance from 3 to 6 km	Progressive load-carriage training (2 sessions/week) and resistance training (3 session/week). Resistance training included mainly 3–5 × 5–10 reps.	**5 km load carriage (23 kg, 5.5 km·h)** Decreased submaximal VO_2 Decreased submaximal RER No change in submaximal RPE No change in submaximal heart rate
Burley et al. (2020) (recruits: 162 men, 52 women)	12 weeks	Experimental training group (EXP)	Basic military training including physical training with emphasisi on resistance training (17 sessions), high-intensity running (8 sessions), load carriage (2 sessions)	~60 min	3–4 days/ week	Progressive resistance training wth 2–3 × 5–8/3 min, Progressive 2–5 high intensity intervals of 3 min, paced load carriage	Total volume of training was 3005 min with 17 resistance training sessions, 8 high-intensity running, 2 load carriage, 3 familiarization sessions, 2 swimming, 3 fitness testing, 2 ropes sessions, 3 obstacle course	**3.2 km load carriage (22 kg)** EXP: decreased time (−156 s) CON: decreased time (−106 s) Greater improvement in EXP compared to CON
		Control group (CON)	Basic military training including extant physical training	~60 min	3–4 days/ week	Moderate-high intensity running (9 sessions), circuit training (7 sessions), load carriage (7 sessions)	Total volume of training was 3010 min with 6 moderate to high-intensity running sessions, 7 circuit training, 7 load carriage, 3 swimming, 3 fitness testing, 4 obstacle course, 10 familiarization/skills training	

basic training course. Over the course, the training regimen was biased toward strength related activities (28 h) and aerobic training (15 h), with agility, material handling, sports, circuit training and swimming allocated a further 28 h of training time. In comparison to the findings of Williams, Rayson, and Jones (1999) material handling performance was improved at 1.45 m, but lifting capacity at 1.70 m and repetitive lifting were not improved (Williams et al., 2002).

The responsiveness of recreationally active women to concurrent or military style training has been of interest, particularly with respect to gains in muscular strength, power and manual handling performance (Hendrickson et al., 2010; Kraemer et al., 2001; Nindl et al., 2017). All three investigations observed that women are able to make significant improvements in muscular strength and manual handling performance, when exposed to contemporary concurrent strength and endurance training regimen (Hendrickson et al., 2010; Kraemer et al., 2001; Nindl et al., 2017). Over a 12 or 24-week duration, periodised concurrent endurance and strength training significantly improved both maximal and repetitive lifting capacity (Hendrickson et al., 2010; Kraemer et al., 2001; Nindl et al., 2017). Additionally, some of these improvements in upper and lower body 1RM, and repetitive lift and carry were observed after only seven weeks of concurrent training (Hendrickson et al., 2010). Interestingly, despite these improvements in strength, no improvement was observed in upper- (throw) or lower-body (squat jump) power (Hendrickson et al., 2010). The absence of improved muscle power contrasted the findings of Kraemer et al. (2001) and Nindl et al. (2017), who both observed significant improvements in upper and lower limb power in women. Importantly, in these investigations the training regimen for the development of whole body strength and power, incorporated aerobic training as a supplemental activity (twice a week) in contrast to Hendrickson et al. (2010), who required participants in the concurrent regimen to perform three endurance sessions each week and on the same day as the resistance training session. The bias therefore was more evenly distributed between strength and endurance training than observed in the regimen utilized by Kraemer et al. (2001) and Nindl et al. (2017) which had an increased focused upon the development of muscular strength and power.

Given the responsiveness of women to contemporary resistance training, Kraemer et al. (2001) and Nindl et al. (2017) noted that after six months of dedicated training, mean female strength improved significantly but it did not exceed the absolute strength scores of untrained males. However, repetitive lift performance improved significantly irrespective of the style of six-month resistance training regimen, where no difference in absolute performance was observed between the trained females and untrained males (Kraemer et al., 2001; Nindl et al., 2017) (Table 2).

Casualty evacuation

Harman et al. (2008) reported in untrained and recreationally active male civilians that eight-weeks of concurrent resistance and aerobic training improved casualty evacuation performance. Improvements were similar in combined strength and aerobic group and the Army Standardized Physical Training which relied on the use of body weight exercises (Harman et al., 2008) (Table 3). While Hendrickson et al. (2010) studied the effects of eight-weeks of combined aerobic and strength training in recreationally active civilian women on occupational military performance, including casualty evacuation performance (50 m mannequin drag). Despite significant improvements in upper- and lower-body strength and aerobic capacity, as well as repetitive lift and carry, there was no change in casualty evacuation performance (Table 3).

Among US Army active duty soldiers, a seven-week combined aerobic and whole-body resistance training programme that also included agility and lower-body power exercises, resulted in superior improvement in casualty evacuation performance compared to traditional army physical training consisting of calisthenics and aerobic training (Lester et al., 2014) (Table 3). Solberg et al. (2015) studied the effects of six-month linear periodization combined training followed by a six-month non-linear training period in highly trained Special Forces Operators with five to six training sessions/week. The training was further block-periodized to focus on either strength or aerobic fitness. The Special Forces Operators showed a small improvement in evacuation performance after the linear periodization training period and moderate improvement following the non-linear training period (Table 3).

Discussion

In the present review, the purpose was to characterize the main physical attributes related to the most common military occupational tasks: load carriage, manual material handling, and casualty evacuation. Based upon this evidence the further aim was to review the available physical training intervention studies to explore the effectiveness of physical training modifications in military settings to improve these specific occupational military tasks. We discuss the findings observed and suggest practical applications related to physical training for recruits and active-duty soldiers.

Table 2. Physical training intervention studies on manual material handling performance.

Study, (study sample)	Training model: Duration	Group	Mode	Session duration	Frequency	Intensity	Other physical training details	Manual material handling performance
Hendrickson et al. (2010) (56 civilian females)	8 weeks	Aerobic (A), $n = 13$	Aerobic training	20–50 min	3 days/week	Distance running 70–85% Hrmax, intervals near maximal speed	2 distance runs/week, 1 interval running/week	**5-min repetitive lift and carry:** 20 kg to 1.55 m box lift and 3 m carry: S: improvement (+31%) A: improvement (+23%) COMB: improvement (+36%) CON: improvement (+18%) C improved more than C
		Strength (S), $n = 18$	Periodized resistance training	40–63 min		variance within 3 × 3–12 repetitions/90–120 s. recovery	Non-linear periodized training	
		Combined (COMB), $n = 15$	Aerobic and periodized resistance training	60–90 min		exercised both the training programme of S and A	S and A trained in the same session. S training performed first followed by A	
		Control (CON), $n = 10$	No physical training	–	–	–	No formalized training, maintain normal activity level	
Kraemer et al. (2001) (civilians: 100 men, 93 women)	24 weeks	Total body strength/power (TP), $n = 17$	Periodized resistance training	60–90 min	3 days/week	3–8 repetitions/2 min recovery	Total body training groiups included hip and leg exercises which the upper body training groups did not include. The upper body groups did additional upper body exercises to help equate total work. Resistance band training in the aerobic group was done to provide a similar component to the other groups in order to improve compliance/ adherence	**1RM box lift, 1.32 m height:** TP, TH, UP, UH: linear improvements throughout the training period (3, 6 months) FLD: improvement at 6 months AER: no change**10-min repetitive box lift, 20.5 kg, 1.32 m height:** TP, TH, UP, UH: linear improvements throughout the training period (3 months, 6 months) FLD: improvement at 6 months AER: mprovement at 6 months
		Upper body strength/power (UP), $n = 18$				3–8 repetitions/2 min recovery		
		Total body strength/ hypertrophy (TH), $n = 18$				8–12 repetitions/30–90 s recovery		
		Upper strength/ hypertrophy (UH), $n = 15$				8–12 repetitions/30–90 s recovery		
		Field exercise (FLD), $n = 14$	Ballistic plyometric and partner resisted exercises			10–25 repetitions/60 s recovery		
		Aerobic (AER), $n = 11$	Running and calisthenics + supplemental resistance band exercises	25–60 min		Moderate-intensity running, circuit training (10 reps per movement/circuit, 60 s recvery between circuits)		
Williams et al. (2002) (recruits: 43 men, 9 women)	10 weeks	Basic training with modified physical training (PT)	Combined strength and aerobic training with mnaula material handling, and other sports	40 min	71 exercise sessions during the 10-week period (resistance training 2 days/ week)	Strength training: 3–4 × 75–100%/6RM, 1-min recovery Aerobic training typically 80-min with intervals followed by load carriage	Physical training consisted of 71 sessions of 40 min exercise: strength training (28), endurance training (15), agility (8), MH (6), sports (6), circuit-training (4) and swimming (4). Basic training included load carriage and military drills (40 min)	**1RM box lift:** 1.45 m box lift: improvement (+12%) 1.70 m box lift: improvement (+8%) **10-min repetitive lift and carry**: 10 kg to 1.45 m box lift and 10 m carry: improvement (+15%) 22 kg 1.45 m box lift and 10 m carry: improvement (+19%) Modified PT induced greater improvement in 1.45 box lift compared to normal BT (Williams et al., 1999)

(*Continued*)

Table 2. Continued.

Study, (study sample)	Training model: Duration	Group	Mode	Session duration	Frequency	Intensity	Other physical training details	Manual material handling performance
Nindl et al. (2017) (civilians: 18 men, 40 women)	24 weeks	Traing group (only women)	Resistance, aerobic, and load carriage training	Limited at 90 min/ day	Limited at 5 days/week	RT: load prescribed so that participants could complete repetitions, but not additional repetitions: Running: physically demanding pace for an individual Load carriage: 6.4 km/ h with progressive load	Weeks 1–18: RT 4 days/week and Running 2 days/week Weeks 19–24: RT 2 days/week with double volume. After week 14 load decreased and reps increased + possibility to include interval running at faster speeds. 8 km progressive load carriage with 11–34 kg by the end of training	**1RM box lift**: 76 cm box lift: improvement (+33%) 132 cm box lift: improvement (+30%) from 76 to 152 cm box lift (+47%) **10-min repetitive lifts**: 18 kg to 132 cm box lift (+32%) 18 kg, 132 cm lift and 8 m carry (+18%)
Control group at baseline (only men)								
Burley et al. (2020) (recruits: 162 men, 52 women**)**	12 weeks	Experimental training group (EXP)	Basic military training including physical training with emphasisi on resistance training (17 sessions), high-intensity running (8 sessions), load carriage (2 sessions)	~60 min	3–4 days/week	Progressive resistance training wth 2–3 × 5–8/3 min, Progressive 2–5 high intensity intervals of 3 min, paced load carriage	Total volume of training was 3005 min with 17 resistance training sessions, 8 high-intensity running, 2 load carriage, 3 familiarization sessions, 2 swimming, 3 fitness testing, 2 ropes sessions, 3 obstacle course.	**1RM box lift, 1.5 m height:** EXP: increased (+4.8 kg) CON: increased (+1.3 kg) Greater improvement in EXP compared to CON
		Control group (CON)	Basic military training including extant physical training	~60 min	3–4 days/week	Moderate-high intensity running (9 sessions), circuit training (7 sessions), load carriage (7 sessions)	Total volume of training was 3010 min with 6 moderate to high-intensity running sessions, 7 circuit training, 7 load carriage, 3 swimming, 3 fitness testing, 4 obstacle course, 10 familiarization/ skills training	

Table 3. Physical training intervention studies on casualty evacuation performance.

Study, (study sample)	Training model						Other physical training details	Casualty evacuation performance
	Duration	Group	Mode	Session duration	Frequency	Intensity		
Harman et al. (2008) (32 civilian males)	8 weeks	Resistance training group (RT)	Resistance training, runs, sprints, agility, load carriage	90 min	5 days/week	To the best of their ability, load carriage at 6.4 km/h	Pace 90 sec/set progressive load carraige (0–33 kg), sprints varied 100–800 m	**Casualty evacuation test** **(50 m run + 80 kg mannequin drag 50 m)** RT: decreased time (−23%) CON: decreased time (−36%) No differences in improvements between groups
		Army standardized physical training group (CON)	calisthenics, drills, sprints, distance running, stretching	90 min	5 days/week	To the best of their ability	Standardized sets and repetitions in calisthenics, running pace adjusted to fitness level	
Hendrickson et al. (2010) (56 civilian females)	8 weeks	Aerobic (A), $n = 13$	Aerobic training	20–50 min	3 days/week	Distance running 70–85% Hrmax, Intervals near maximal speed	2 distance runs/week, 1 interval running/week	**Casualty evacuation test** **(50 m run + 61 kg mannequin drag 50 m)** S: no change A: no change COMB: no change CON: no change
		Strength (S), $n = 18$	Periodized resistance training	40–63 min		Variance within 3 × 3–12 repetitions/90–120 s recovery	Non-linear periodized training	
		Combined (COMB), $n = 15$	Aerobic and periodized resistance training	60–90 min		Exercised both the training programme of S and A	S and A trained in the same session. S training performed first followed by A	
		Control (CON), $n = 10$	No physical training	–	–	–	No formalized training, maintain normal activity level	
Lester et al. (2014) (133 male active duty soldiers)	7 weeks	Novel training regimen (NT), $n = 94$	Resistance training (RT), speed, agility, and power (SAP), core stability (CR), flexibility (F), load carriage 16–32 kg (LC)	CR 15 min, F 15 min, RT 60 min SAP 60 min LC 90–180 min	CR 4 × week, F 5 × week, RT 2 × week, SAP 2 × week, LC 1 × week	Each set in resistance training repeated to fatigue	MIlitary training similar for both groups	**Casualty evacuation test** **(50 m run + 80 kg mannequin drag 50 m)** NT: decreased time (−17%) CON: increased time (+15%)
		Control (CON): traditional army physical training regimen, $n = 39$	Normal daily PT exercises, including calisthenics and running exercises	Not reported	Daily physical training	Based on individual capacity		
Solberg et al. (2015) (22 male special operators)	52 weeks	24 week linear periodization training (LP) followed by 24 week non-inear periodization trainining (NLP)	Linear periodization consisting of RT and aerobic training	Not reported	5–6 sessions/ week	2 blocks of 3 months: - hypertrophy (3 × 10RM) - strength (4 × 5RM) - maximal strength (5, 3, 1 RM) between all strength blocks (1–3 w) mixed aerobic training:	A training week conissted of 1–2 training sessions directed to improve the weakest physical fitness dimension	**Casualty evacuation test** **(100 m run + 80 kg mannequin drag 100 m)** LP (0–6 months): no improvement NLP (7–12 months): decreased time (−10%)
			Non-Linear Periodization oscillating between strength and aerobic training	Not reported	5–6 sessions/ week	Alternating aerobic and strength blocks: - muscular endurance - strength (5–6RM) - hypertrophy: (8–10RM) - mixed aerobic training (60–90% HRmax)		

Load carriage

Load carriage performance requires both aerobic and neuromuscular fitness with greater emphasis on maximal strength and absolute maximal oxygen uptake, especially when carrying heavier loads (i.e. >25 kg) (Fallowfield et al., 2012; Lyons et al., 2005; Rayson et al., 2000; Terho et al., 2018). The systematic review by Knapik et al. (2012) reported that the greatest improvements in load-carriage performance were observed when load carriage training was accompanied whole-body strength and aerobic training. Recent studies in both recruits (Burley et al., 2020) and active-duty soldiers (Heilbronn et al., 2020) support this finding. In addition, load carriage training together with whole-body strength training has been shown to induce moderate psychophysiological responses to a submaximal load carriage task (Wills et al., 2019; Wills et al., 2020).

Knapik et al. (2012) also reported that field training including a wide variety of activities such as sandbag-lifts, plyometrics, agility, hill running, aerobic training and manual material handling, effectively improved load carriage performance. Although, field-based training has been shown to be effective in improving load carriage performance it must be noted that three of the four studies in the systematic review were in recruits, and the remaining study involved civilian participants. Additional findings from Santtila et al. (2010) are consistent with these results while recent observations from Heilbronn et al. (2020) also partially support these findings. Active-duty soldiers improved fire and movement performance (15 kg), but not loaded run (15 kg) and loaded marching (45 kg) performance, following 15 weeks of physical training that comprised aerobic training and loaded combat-related tasks (loaded march, fire and movement, jerry can carry). Although observational studies have consistently shown a relationship between aerobic fitness and load carriage performance (e.g. Rayson et al., 2000), training studies focused on aerobic fitness have shown the lowest training effect when compared to other training modalities (Knapik et al., 2012). This indicates that load-carriage performance is a result of a combination of physical fitness components, with an emphasis on muscular strength with increasing external loads.

Interestingly, Vaara et al. (2015) and Groeller et al. (2015) reported in recruits and trainees respectively, that even in the absence of improvements in physical fitness (aerobic capacity, maximal strength, lower-limb power), load carriage performance (3.2 km, 22–27 kg) was improved following military training. These results indicate that in populations with limited to no previous load carriage experience (compared with experienced active-duty soldiers) performance can improve in the absence of targeted physical training.

Manual material handling

In manual material handling, the most important physical attributes for discrete lifting tasks are maximal strength and power (Hauschild et al., 2017; Hydren et al., 2017; Rayson et al., 2000) while muscular strength, muscular endurance and aerobic fitness are associated with repetitive lifting performance (Hauschild et al., 2017; Rayson et al., 2000). Observational studies in recruits show both improvement (Drain et al., 2015) and no change (Williams et al., 1999) in manual material handling during a period of basic training; while a consecutive training period showed improvement in carrying tasks, but not in maximal lifting capacity (Groeller et al., 2015). Physical training intervention studies, however, report that an emphasis on combined strength and aerobic training may improve maximal lifting capacity (Burley et al., 2020; Williams et al., 2002) and repetitive lifting performance (Williams et al., 2002) during military service. High aerobic training load experienced in military service (Santtila et al., 2010; Jurvelin, Tanskanen-Tervo, Kinnunen, Santtila, & Kyröläinen, 2020) may interfere with strength development and therefore compromise manual material handling performance, such as maximal lifting capacity as evidenced by Williams et al. (1999).

Combined strength and aerobic training has been shown to improve maximal lifting capacity, repetitive lifting (Kraemer et al., 2001; Nindl et al., 2017), and lifting and carry test performances (Nindl et al., 2017), whereas different modalities of strength training were effective in improving maximal lifting capacity (Kraemer et al., 2001). In addition, both strength training and aerobic training were effective to improve repetitive lifting performance (Kraemer et al., 2001). In another study with strength, aerobic, and combined strength and aerobic training groups all improved their 5-min repetitive lift and carry performance (Hendrickson et al., 2010). Considering the current evidence strength training is recommended for soldiers to improve maximal strength and thereby also manual material handling performance.

Casualty evacuation

Maximal strength including grip strength, muscular endurance, absolute maximal oxygen uptake and anaerobic capacity are important predictors of casualty evacuation performance (Angeltveit et al., 2016; Arvey et al., 1992; Michaelides et al., 2011; Rhea et al., 2004). Combined strength and aerobic training improved casualty evacuation performance in a similar fashion independent of whether the training included strength training with an external mass or by using participants' own body weight as resistance in untrained participants (Harman et al., 2008). On the other hand, in recreationally active participants neither strength, aerobic combined, or control group improved casualty evacuation performance at a group level during an eight-week training period, although generic physical fitness improved (Hendrickson et al., 2010). Nevertheless, weak to moderate relationships between changes in generic physical fitness and changes in casualty evacuation performance were observed (Hendrickson et al., 2010) indicating the ability to improve casualty evacuation performance through improvements in generic fitness abilities. It may, however, be that the recreationally active background and higher physical fitness of the participants induced no improvement (Hendrickson et al., 2010) compared to untrained subjects (Harman et al., 2008), which is congruent with Coffey and Hawley (2017) reporting that untrained participants seem to benefit from concurrent training similarly when compared to training each mode separately. However, individuals with a longer training background seem to be more susceptible to an interference effect (Coffey & Hawley, 2017). Nevertheless, casualty evacuation performance has improved also in well-trained soldiers (Lester et al., 2014; Solberg et al., 2015) with physical training including higher volume compared to studies in untrained and recreationally active participants (Harman et al., 2008; Hendrickson et al., 2010). Finally, although there are no studies that have directly investigated the link between changes in anaerobic fitness or grip strength and changes in casualty evacuation, observational studies (Angeltveit et al., 2016; Arvey et al., 1992; Michaelides et al., 2011; Rhea et al., 2004) indicate that anaerobic capacity and grip strength are associated with casualty evacuation performance.

Physical training considerations for recruits to improve military occupational performance

Based on observational data, load carriage (Santtila et al., 2010; Vaara et al., 2015) and manual material handling (Drain et al., 2015; Groeller et al., 2015; Williams et al., 2002), including simulated casualty evacuation (Groeller et al., 2015), can be improved during the initial military service training. However, modified physical training, when compared to traditional military physical training, or supplementary physical training during military training shows greater improvements in load carriage and manual material handling (Burley et al., 2020; Williams et al., 2002), although contrasting findings have also been observed (Santtila et al., 2010; Vaara et al., 2015).

One of the major challenges in optimizing physical training adaptations in military training is the fact that recruits undertake numerous physically and physiologically demanding activities outside the dedicated physical training resulting in a high volume of low and moderate intensity physical activity (Jurvelin et al., 2020), which may compromise strength and especially explosive power development (Santtila et al., 2010). This so-called interference effect refers to blunted training adaptations, specifically development of maximal strength, muscle power and hypertrophy when combining strength and aerobic training (Kraemer et al., 1995). Thus, it is possible that physiological strain from high-volume, low-intensity military training, combined with disturbed sleep, induces activation of molecular signalling pathways that are antagonistic to muscle protein synthesis and therefore, optimal strength development (Church, Gwin, Wolfe, Pasiakos, & Ferrando, 2019; Fyfe et al. 2014) in military training.

The results from the present review indicate that physical training for recruits and soldiers should include a combination of strength and aerobic training with a greater emphasis on strength training given its important role in supporting performance of the essential occupational tasks included in this review. For optimal strength development, it is recommended that unnecessary low to moderate aerobic activity that often pervades military training is identified and reduced. Given the contextual limitations, physical training within the military needs to provide the required training stimulus while balancing this against the total training load and stress exposure to ensure gains in physical fitness and occupational performance including load carriage, manual material handling and casualty evacuation. Recent findings from Burley et al. (2020) suggest that the benefits of high-intensity strength and aerobic training in military service are realized when they replace traditional higher volume moderate intensity physical training activities such as continuous running and circuit training. Emphasis on lower volume but higher intensity appears to be a feasible and effective training mode to optimize training adaptations in recruits.

Physical training considerations for active-duty soldiers to improve military occupational performance

The studies reviewed herein vary according to their training duration, intensity, frequency and volume among other physical training constructs and in military environment external psychophysiological stress may vary as well affecting training adaptations. Therefore, when designing training programmes for active-duty soldiers, it is important to consider the context and task requirements as the foundation for the training programme (Nindl et al., 2015) as they can markedly vary in different military tasks and environments. A need for specificity, variation, and progression in training stimulus are the most important factors when considering the development of maximal or explosive strength and maximal aerobic capacity (Friedl et al., 2015; Kyröläinen et al., 2018; Nindl et al., 2015; Nindl, Jones, Van Arsdale, Kelly, & Kraemer, 2016) for load carriage, manual material handling and casualty evacuation performance.

Load carriage, manual material handling and casualty evacuation tasks all require physical fitness to safely and effectively complete these tasks. On the other hand, in prolonged operational settings, the combination of sleep restriction, energy deficit and high physical demands are likely to impair combat readiness (Castellani et al., 2003; Nindl et al., 2006). However, increased physical fitness can assist in buffering these occupational stressors. Even in the absence of operational or combat stressors, active duty soldiers undertake many physically and physiologically demanding activities. Therefore the total training exposure should be assessed, along with recovery opportunities, when prescribing training régimen. One of the principle goals of physical training in active-duty soldiers is to develop and maintain physical fitness at the required level prior and between operations in order to successfully accomplish given occupational tasks, even in physiologically demanding scenarios.

Military occupational tasks reviewed herein all require combination of physical fitness attributes to be developed, and the foundation in physical training lies in combining strength and aerobic training (Kyröläinen et al., 2018). The results of the present review particularly emphasize the role of muscular fitness in successful performance of the reviewed military occupational tasks. However, in addition to inter-individual differences in training status and adaptations, different tasks may require different emphasis in the training programme to develop specific physical fitness components. For example, anaerobic capacity and grip strength are attributes needed in casualty evacuation performance and in addition to combined strength and aerobic training they should be trained accordingly. The role of specific occupational physical training is still largely unknown and deserves future military studies. Nevertheless, "specificity" training, widely used in elite athletes (Reilly, Morris, & Whyte, 2009), do indirectly support this type of training, for example in order to improve load carriage the training programme could include specific load carriage exercises (Nindl et al., 2016). However, the application of more contemporary physical training strategies with a focus on higher intensity and lower volume load carriage activities is advocated, rather than traditional load carriage training that involves prolonged moderate intensity activities.

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No potential conflict of interest was reported by the author(s).

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