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Positive, limited and negative responders: The variability in physical fitness adaptation to basic military training

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Positive, limited and negative responders: The variability in physical fitness adaptation to basic military training

Abstract

Objectives: To investigate the heterogeneity of physical adaptation in Australian Army recruits completing a 12-week basic military training regimen.

Design: A prospective research design.

Methods: Volunteer recruits (n = 195) completed 12-weeks of basic military training. Recruit physical fitness was assessed at week 1, weeks 6–8 and week 12. Recruits in the upper (75th) and lower (25th) quartiles for each assessment were then analysed using a repeated measures two-way ANOVA. The relative magnitude of recruit adaptions were classified as positive response ($R_{positive}$, ≥5%), limited response ($R_{limited}$, >−5% to <5%) and negative response ($Rn_{egative,}$ ≤−5%); Chi-square analysis determined the proportional differences in the distribution of each quartile.

Results: An interaction (p < 0.001) was observed in the lower and upper recruit quartiles for all assessments of physical fitness at each time point. After 12 weeks of military training the mean difference of the highest quartile was; 20-m multi-stage fitness test 7.4 $mL \cdot kg^{-1} \cdot min^{-1}$, (CI:5.8:9.1), 2-min push-ups 20.1 reps, (CI:16.2:23.9), 1RM box lift 5.6 kg, (CI:2.6:5.8) and load carriage 222.1 s, (CI:174.7:269.4) compared to the lowest recruit quartile. The highest quartile demonstrated no improvement in 1RM box lift (−4%, −1%) and push-ups (2%, 0%) performance at weeks 6–8 and week 12 respectively. In contrast, adaptations in the lowest quartile for 1RM box lift (16%, 21%) and push-ups (46%, 46%) over the same time periods were observed.

Conclusions: A significant proportion of recruits may complete basic military training with a decline in physical performance. Higher relative-intensity cardiorespiratory and resistance exercise should be considered to facilitate physical adaptation in all recruits.

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Positive, limited and negative responders: The variability in physical fitness adaptation to basic military training

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ABSTRACT

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Conclusions: A significant proportion of recruits may complete basic military training with a decline in physical performance. Higher relative-intensity cardiorespiratory and resistance exercise should be considered to facilitate physical adaptation in all recruits.

1. Introduction

Considerable evidence exists for the mean group response to basic military training in recruit physical fitness[1–3] and occupationally-relevant physical performance.[4–6] However, our existing understanding of the heterogeneity of cardiorespiratory endurance adaptations during military training is limited.[7] Furthermore with respect to muscular strength, an essential physical attribute for military service,[8] inter-individual variability in response to basic military training has not previously been described.

Basic military training is characterised by a requirement to train large numbers of recruits in a field-expedient manner with a focus upon cardiorespiratory endurance and prolonged moderate intensity exercise.[1,8] These characteristics have been cited as contributing factors to the modest rates of physical adaptation observed.[4,7,9] Additionally, improvements recorded in physical performance during basic military training are not evenly distributed, with significant gains in cardiorespiratory endurance observed only in the least aerobically fit recruits.[7] The absence of positive adaptation in recruits with higher initial levels of cardiorespiratory endurance has been attributed to a lack of individualisation and insufficient exercise stimulus.[3,7] Indeed, a reduction in cardiorespiratory endurance has been indirectly reported in recruits after completion of military training.[3]

Manual materials handling and load carriage tasks are critical and enduring requirements of military service.[10,11] Moreover, during deployment, these activities are associated with the highest incidence of injury.[12] Yet muscular strength, a requisite physiological attribute for the successful completion of these tasks,

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is traditionally not emphasised within basic military training.[8,13] Therefore, this investigation determined the heterogeneity of adaptation in physical fitness of recruits based upon the initial performance levels in muscular strength, muscular endurance, load carriage and cardiorespiratory endurance.

2. Material and methods

Prior to commencement of the Australian Army 12-week basic military training regimen at Blamey Barracks, Kapooka, Australia, recruits were required to achieve a minimum standard of fitness: push-ups (8 female and 15 male repetitions), sit-ups (45 repetitions) and reach Level 7 Shuttle 5 (38.2 $mL\cdot kg^{-1}\cdot min^{-1}$) of the 20-m multistage fitness test (MSFT). In this investigation recruits (n = 280) each provided voluntary written informed consent to participate in the study which was approved by the Australian Defence Human Research Ethics Committee (645-11).

A prospective research design was utilised to assess one-repetition maximum (1RM) box lift, 3.2 km 22-kg load carriage, 2-min push-ups, and 20-m multi-stage fitness test performance at three time points (week 1, weeks 6–8 and week 12) across the 12-week regimen. The assessments were implemented over a two-day period to ensure sufficient rest between each assessment with participants instructed to provide a maximal effort in each test.

Push-ups performance was determined over a 2-min period, where recruits were instructed to complete as many repetitions as possible within the allotted time.[1] Cardiorespiratory endurance was assessed using the MSFT. Recruits repeatedly ran between two parallel lines set 20 m apart, with the speed increasing by 0.5 $km\,h^{-1}$ at each level until volitional termination. Peak oxygen uptake ($\dot{V}O_{2peak}$ $mL\cdot kg^{-1}\cdot min^{-1}$) was then estimated.[14] 1RM box (360 × 360 × 360 mm) lift was determined on the peak mass (kg) lifted in a single repetition to a height of 1.5 m. The assessment began with an eight repetition warm up using a 10-kg box, the mass then varied in 2.5-, 5- or 10-kg increments.[1] Between each box lift attempt, a 2-min rest period was provided. A 3.2-km load carriage assessment using a 22-kg weighted vest (MiRVest Inc, CA, United States) was conducted on a 400-m synthetic running track. Recruits were released in pairs every 15 s with the first lap at best walking pace, and the remaining seven laps completed at best pace with elapsed time in seconds recorded.[1]

The basic military training regimen consisted of 41 dedicated physical training sessions that were classified as; circuit training (7), cardiorespiratory endurance (10), load carriage (7), military skills (13) and physical assessments (4). Circuit training required recruits to complete ten multi-joint exercises in series performing a maximal number of repetitions within a 60-s period prior to transitioning to the next exercise. Cardiorespiratory endurance consisted of running (6) and swimming (4) sessions using primarily a continuous training format with the rest periods within each session typically determined by the slowest recruit. An external load (10–22 kg) was applied for load carriage sessions over a distance of 2–7 km while wearing military uniform (trousers, shirt and boots; ∼3.9 kg) and marching at a fixed speed (∼5.5 $km\cdot h^{-1}$). Both external load and distance increased incrementally with each session. Military skill sessions consisted of rope climbing, obstacle courses and battlefield simulation training sessions.

Recruits were categorised into quartile groupings based upon the initial (week 1) levels of performance for each of the physical assessments. A two-way repeated measures analysis of variance (ANOVA) was performed to determine if an interaction between lower (25th quartile) and upper (75th quartile) groupings over time was present. Where a significant interaction was observed a Sidak's multiple comparisons test was utilised to determine the location of the significant difference. A univariate ANOVA was used to determine the main effect for the entire cohort for each assessment. Responsiveness of recruits were categorised to encapsulate the typical error of measurement for the physical assessments[15,16] into three classifications; positive response ($\mathbf{R}_{positive}$, ≥5%), limited response ($\mathbf{R}_{limited}$, >−5% to <5%) or negative response ($\mathbf{R}_{negative}$, ≤−5%). For the contingency tables, a bivariant analysis using the Chi-square test was performed. Statistical analysis was performed using Graphpad Prism (Version 6.1, Graphpad Software, San Diego, California, USA). All analyses were conducted using an alpha of $p < 0.05$ with data reported as mean ±95% confidence intervals (CI), unless otherwise stated as standard deviation (SD).

3. Results

One hundred and ninety five (195) recruits completed the investigation (173 males and 22 females, stature 1.77 ± 0.07 m, mass 76.2 ± 12.4 kg and age 21.5 ± 4.2 y), with 85 recruits withdrawn due to either injury, failure to meet minimum assessment standards, transfer to another platoon, military discharge or incomplete data. No change ($p > 0.05$) in body mass, 0.3 kg (CI: −0.5:1.1) was recorded following 12 weeks of basic military training. However, body mass was observed to regress to the mean, with recruits in the lowest quartile gaining ($p < 0.05$) body mass after weeks 6–8, 2.5 kg (CI: 1.6:3.3) and week 12, 4.0 kg (CI: 3.0:5.1) of basic military training. In contrast, the heaviest 25% of recruits lost ($p = 0.01$) body mass, −3.6 kg (CI: −2.2:−4.9) and −4.3 kg (CI: −2.6:−6.0) at weeks 6–8 and week 12 respectively.

An improvement ($p < 0.001$) in estimated cardiorespiratory fitness was observed after weeks 6–8, 4.9 $mL\cdot kg^{-1}\cdot min^{-1}$ (CI: 4.3:5.4) and week 12, 3.7 $mL\cdot kg^{-1}\cdot min^{-1}$ (CI: 3.0:4.4) of training (Table 1). An interaction ($p < 0.001$) was observed between the lower and upper quartiles at week 1, −10.9 $mL\cdot kg^{-1}\cdot min^{-1}$ (CI: −12.5:−9.3), weeks 6–8, −8.8 $mL\cdot kg^{-1}\cdot min^{-1}$ (CI: −10.4:−7.2) and week 12, −7.4 $mL\cdot kg^{-1}\cdot min^{-1}$ (CI: −9.1:−5.8) with the greatest improvements occurring in recruits with the lowest cardiorespiratory fitness (Fig. 1A).

Upper-body muscular endurance improved ($p < 0.001$) after weeks 6–8, 6.6 reps (CI: 5.2:8.0) and week 12, 6.6 reps (CI: 5.2:8.0) compared to week 1, however no change in push-ups performance was observed between weeks 6–8 and week 12 (Table 1). An interaction ($p < 0.001$) was observed between the lower and upper quartiles at week 1, −30.9 reps (CI: −34.7:−27.0), weeks 6–8, −21.1 reps (CI: −25.0:−17.3) and week 12, −20.1 reps (CI: −23.9:−16.2) of basic training (Fig. 1B). Furthermore, only recruits in the lowest quartile demonstrated improved ($p < 0.001$) push-ups performance in weeks 6–8, 10.3 reps (CI: 7.8:12.8) and week 12, 10.4 reps (CI: 8.3:12.4) compared to week 1.

One repetition maximum box lift strength improved by 2.7 kg (CI: 1.7:3.7) and 3.6 kg (CI: 2.5:4.7) in weeks 6–8 and week 12 of training respectively compared to week 1 (Table 1). With an improvement ($p = 0.018$) in box lift performance also observed between weeks 6–8 and week 12 of 0.9 kg (CI: 0.12:1.7). An interaction ($p < 0.001$) was observed between the lower and upper quartiles at week 1, 28.6 kg (CI: 32.3:24.9), weeks 6–8, 22.0 (CI: 25.7:18.3) and week 12, 22.2 kg (CI: 25.9:18.45) of basic training (Fig. 1C). However, compared to week 1, only the lower quartile displayed enhanced ($p < 0.001$) 1RM box lift strength at weeks 6–8, 4.2 kg (CI: 2.6:5.8) and week 12, 5.6 kg (CI: 2.6:5.8) with a 1.4 kg (CI: 0.3–2.4) improvement ($p = 0.011$) between weeks 6–8 and week 12 (Fig. 1C). In contrast, box lift performance in the upper quartile declined ($p < 0.001$) between week 1 and weeks 6–8, 2.3 kg (CI: 0.8:3.9) with no change ($p > 0.05$) observed in box lift performance after 12 weeks of basic training.

Load carriage improved from week 1 by 118.5 s (CI: 100.1:136.8) and 116.6 s (CI: 96.4:136.8) in weeks 6–8 and week 12, respectively

Table 1
Physical performance changes after 6–8 weeks and 12 weeks of basic military training.

Measure	Group	n	Week 1	Weeks 6–8	Week 12	Change (%)	
						Week 1–6/8	Week 1–12
1RM box lift (kg)	All	182	41.2 ± 12.0	43.9 ± 11.2[c]	44.8 ± 10.9[c,d]	8 ± 15%	11 ± 16%
	Lower	49	27.3 ± 5.8	31.5 ± 7.9[c]	32.8 ± 8.4[c,d]	16 ± 16%	21 ± 16%
	Upper[a]	49	55.8 ± 6.7[b]	53.5 ± 8.9[b,c]	55.0 ± 7.9[b]	−4 ± 8%	−1 ± 11%
Push-ups (reps)	All	184	38.5 ± 12.7	45.1 ± 11.4[c]	45.1 ± 10.8[c]	21 ± 18%	22 ± 21%
	Lower	52	24.2 ± 5.7	34.5 ± 8.4[c]	34.5 ± 8.4[c]	46 ± 36%	46 ± 30%
	Upper[a]	47	55.1 ± 6.7[b]	55.6 ± 9.6[b]	54.6 ± 7.2[b]	2 ± 16%	0 ± 14%
Est $\dot{V}O_{2peak}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	All	178	43.7 ± 4.6	48.7 ± 4.6[c]	47.5 ± 4.8[c,d]	12 ± 7%	9 ± 9%
	Lower	54	39.1 ± 0.8	44.2 ± 3.1[c]	43.9 ± 3.9[c]	13 ± 8%	12 ± 9%
	Upper[a]	49	50.0 ± 3.2[b]	53.0 ± 3.7[b,c]	51.4 ± 4.6[b,c,d]	6 ± 6%	3 ± 7%
Load carriage (s)	All	168	1267 ± 147.8	1149 ± 115.6[c]	1150 ± 125.8[c]	8 ± 11%	8 ± 8%
	Lower	42	1460 ± 72.2	1257 ± 114.8[c]	1257 ± 121.5[c]	14 ± 8%	13 ± 8%
	Upper[a]	42	1084 ± 62.7[b]	1040 ± 75.1[b,c]	1035 ± 78.5[b,c]	2 ± 17%	4 ± 7%

Notes: Est $\dot{V}O_{2peak}$ = peak oxygen consumption estimated using the multi-stage fitness test. All; complete data set, lower; bottom 25th percentile and upper; highest 75th percentile. All values are mean ± standard deviation.
[a] Denotes a significant interaction.
[b] Denotes a significant difference between the lower and upper quartiles.
[c] Denotes significant ($p < 0.05$) difference to week 1.
[d] Denotes significant ($p < 0.05$) difference to weeks 6–8.

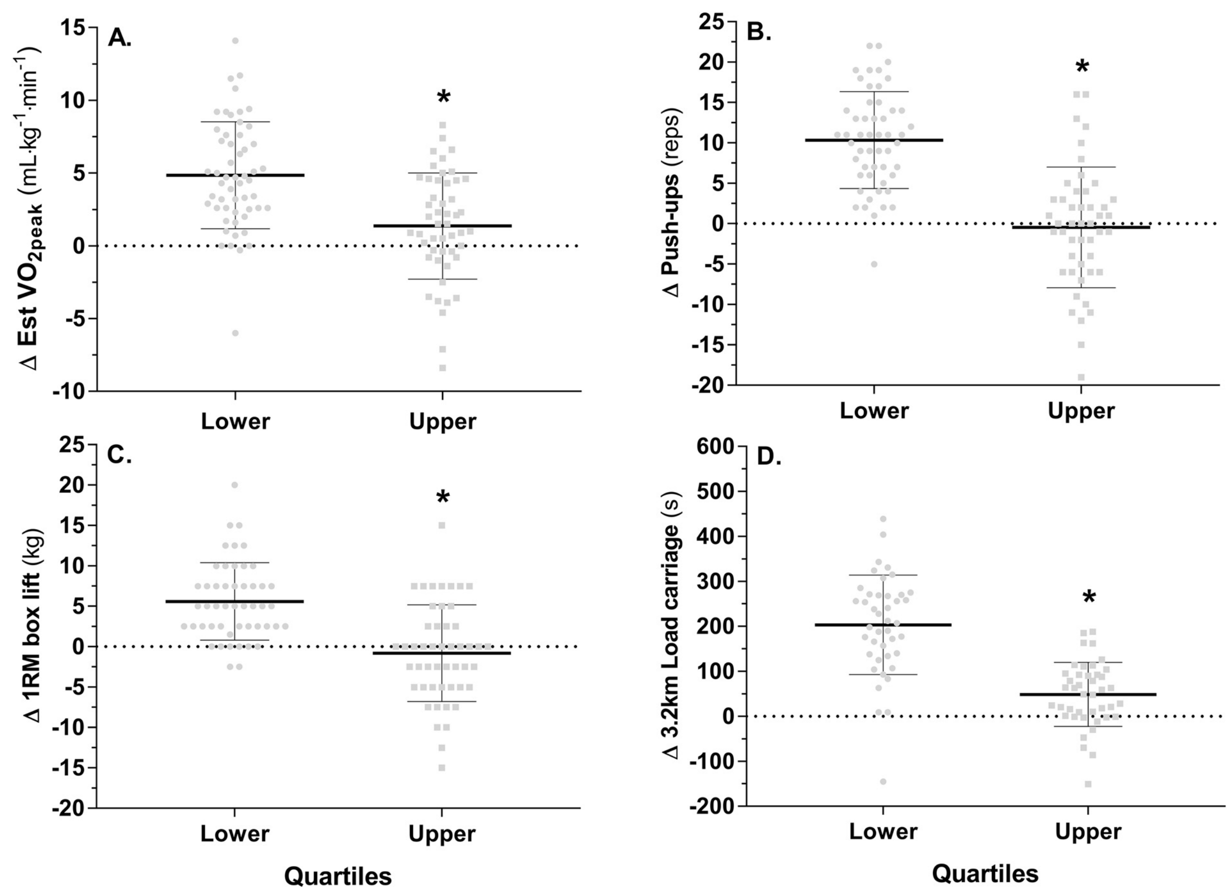

Fig. 1. Change in estimated $\dot{V}O_{2peak}$ (A), 2-min push-ups (B), 1RM box lift (C) and 3.2 km load carriage (D) after 12 weeks of basic military training in the lower (25th percentile) and upper (75th percentile). * Denotes significantly ($p < 0.05$) different from the lower quartile. Grey dots represent individual data points with mean ± standard deviation. A positive change represents improved performance.

(Table 1). However, between weeks 6–8 and week 12 no change in load carriage performance was observed. An interaction ($p < 0.001$) in load carriage time was observed between the upper and lower quartiles at week 1, 376.7 s (CI: 329.4:424.1), weeks 6–8, 217.7 s (CI: 170.1:264.8) and week 12, 222.1 s (CI: 174.7:269.4) of basic training (Fig. 1D). Significant improvements in load carriage performance from week 1 were observed at weeks 6–8, 203.2 s (CI: 161.6:244.9), 44.0 s (CI: 23.5:64.5) and week 12, 203.2 s (CI: 161.7:244.7), 48.6 s (CI: 21.8:75.3) in both the lower and upper quartiles, respectively. The proportional distribution of recruits classified as either $\mathbf{R}_{positive}$, $\mathbf{R}_{limited}$, or $\mathbf{R}_{negative}$ was significantly ($p < 0.001$) different between the lower and upper quartiles for each of the four physical assessments (Table 2).

Table 2
Classification of participants in each quartile according to relative responsiveness.

Assessment	Responsiveness	Lower % (n)	Upper % (n)	All % (n)
1RM box lift				
	Positive	84 (41)	24 (12)	61 (112)
	Limited	12 (6)[a]	41 (20)	24 (43)
	Negative	4 (2)	35 (17)	15 (27)
Push-ups				
	Positive	96 (50)	28 (13)	71 (131)
	Limited	2 (1)[a]	40 (19)	15 (28)
	Negative	2 (1)	32 (15)	14 (25)
Est $\dot{V}$O2peak				
	Positive	81 (44)	35 (17)	69 (122)
	Limited	17 (9)[a]	49 (24)	24 (43)
	Negative	2 (1)	16 (8)	7 (13)
Load carriage				
	Positive	91 (38)	50 (21)	71 (119)
	Limited	7 (3)[a]	43 (18)	24 (42)
	Negative	2 (1)	7 (3)	4 (7)

Notes: Est $\dot{V}O_{2peak}$ = peak oxygen consumption estimated using the multi-stage fitness test. Responsiveness was classified as a change in performance; ≥5% Positive, >−5% to <5% limited or ≤−5% negative.

[a] Denotes a significant difference in the proportional distribution of responsiveness between the lower and upper quartiles.

4. Discussion

An improvement in upper-body local muscle endurance, functional strength, cardiorespiratory endurance and 3.2-km load carriage performance was observed in recruits after 12 weeks of basic training. However, these improvements in physical performance where not homogeneously distributed. Indeed, after 12 weeks of introductory military training 15% (n = 27) and 14% (n = 25) of the recruit cohort had a decline (≤−5%) in performance for functional strength and local muscle endurance, respectively. Furthermore, 7% and 4% of recruits had a reduction (≤−5%) in estimated $\dot{V}O_{2peak}$ and load carriage performance, respectively upon completing basic military training.

Of the four physical performance measures that were conducted, a deterioration of functional strength and local muscle endurance was particularly prevalent in recruits with the highest levels of initial performance. Approximately one-third of recruits in the highest quartile had a reduction (≤−5%) in 1RM box lift (n = 17) and push-ups (n = 15) performance at the completion of 12 weeks of basic training. In contrast, the proportion of $\mathbf{R}_{negative}$, for cardiorespiratory fitness (16%, n = 8) and load carriage performance (7%, n = 3) were significantly lower in recruits within the upper quartile. While a diminished response to physical training has been previously reported in sedentary civilians[17] and military recruits for muscular strength[4] and aerobic fitness,[2,3] this is the first investigation to specifically report upon the incidence of $\mathbf{R}_{negative}$, in physical fitness following basic military training. Additionally, we observed the proportion of $\mathbf{R}_{negative}$, was significantly different between the lower and upper quartiles of recruit fitness. While non- or low-response to physical training have been observed,[18] the loss of fitness during basic military training suggests an insufficient exercise stimulus may be primarily responsible for the lack of positive physical adaptation in these recruits.[19,20]

Prolonged continuous exercise through load carriage or longer distance moderate-intensity running are common physical training methods used to develop cardiovascular endurance within the military.[9] Our investigation observed similar gains in aerobic fitness (~9%) when compared to previous reports (6–10%) of recruit training.[4,5,21] However, within the upper quartile of fitness a 3% improvement in estimated $\dot{V}O_{2peak}$ was observed. These muted improvements in aerobic endurance amongst fitter recruits are likely attributable to insufficient training intensity.[7,19,22] Ross et al.[22] observed for the same energy expenditure, participant non-responsiveness for the development of aerobic fitness was abolished after exposure to a higher intensity (75% $\dot{V}O_{2peak}$) training intervention compared to exercise at 50% $\dot{V}O_{2peak}$. Similarly, in recruits, Dyrstad et al.[7] observed those with the highest relative heart rates during physical training demonstrated the greatest improvements in aerobic fitness. Collectively, the evidence suggests, systematic exposure of recruits to higher relative intensity exercise may be efficacious in all recruits for the development of cardiorespiratory endurance.[9]

Although the development of cardiorespiratory endurance has been a traditional focus of basic military training,[4,8] the most common physically demanding tasks within the Armed Forces of NATO nations are manual materials handling tasks that primarily require the development of muscular strength.[10] Thus, muscular strength should be considered an essential characteristic within basic military training.[8] The results from our investigation also show compared to gains observed in aerobic fitness, a greater number of recruits experienced a loss (≤−5%) in muscular strength, particularly those in the highest quartile. Higher relative resistance training loads (%1RM) elicit superior gains in muscular strength when compared to lighter loads.[23] Furthermore, Sampson et al.[24] reported a divergent response in adaptation of participants who completed a 4-week elbow flexor resistance training familiarisation using a 50% 1RM relative load. Those participants with the highest initial elbow flexor strength had a significantly lower response (~10%), than their weaker peers (~25%). However, when the relative resistance training load was increased to 85% 1RM for a further 12 weeks of resistance training, the observed divergence in adaptive response was eliminated, with both groups improving elbow flexor strength by ~30%.[24] However, there is evidence that when resistance training is performed to volitional termination, both light and heavy loads can elicit comparable gains in muscular strength and hypertrophy.[25,26]

Push-up performance is a common gateway for progression through military training and, accordingly, there is a large focus upon this exercise[1,27] with recruits typically required to perform the activity during each physical training session. It's ubiquitous use in many physically demanding occupations as a proxy measure of strength in both recruits and incumbents exist despite a well-established poor relationship with many essential military activities.[28] Given the importance placed upon this fitness characteristic, we had anticipated a more uniform adaptive response throughout the recruit sample. In contrast, the development of muscular strength and local muscle endurance had similar levels of inter-individual variability, suggesting that basic training is focused upon raising the fitness levels of the least fit recruits.[7] Our results appear to support this proposal, with recruits in the lowest quartile improving push-ups performance by 46%, whereas no change in performance was observed in the upper quartile after 12 weeks of basic military training.

Load carriage is a critical physical requirement for Army personnel. An 8% improvement was observed in 3.2 km load carriage performance, with both the lower (13%) and upper quartile (4%) demonstrating a significant gain in performance during basic training. The improvement observed in load carriage performance occurred between week 1 and weeks 6–8 with performance maintained in the final weeks of basic training. However, this improvement represents the lower bound of adaptive responsiveness (10–18%) previously observed during basic and military-specific physical training.[5,27,29] Whilst cardiorespiratory endurance typically underpins load carriage performance, muscular strength is also an important contributor to load carriage performance.[29] Current evidence suggests increasing the bias toward resistance training, particularly in the upper-body, when delivered concurrently with aerobic fitness or field-specific training yields substantial improvements in load carriage performance.[6,11,30] Furthermore, studies have demonstrated improvements in load carriage performance via strength training alone.[11] The predominance of load carriage and manual materials handling tasks in the Army underline the importance of muscular strength development in recruits during basic training.[10] In addition, individualised exercise prescriptive strategies such as the application of relative exercise training loads (%1RM) may optimise cardiorespiratory endurance and muscular strength adaptation for all recruits.[8]

5. Conclusion

Recruits, with the highest levels of muscular strength and local muscle endurance at the start of basic training were observed to receive no net improvement for these fitness attributes after 12 weeks of military training. Indeed, approximately one third of these recruits had a decline in physical performance of greater than 5% upon completion of basic military training. In contrast, estimated $\dot{V}O_{2peak}$ and load carriage performance improved significantly over the 12-week basic military training course in those with the highest performance scores upon entry. These positive training adaptations, however, were less than those observed in the least fit recruits. These findings suggest higher intensity cardiorespiratory and resistance exercise regimen should be implemented across the training curriculum to facilitate physical adaptation in all recruits.

Practical implication

- Upon completing basic military training, ~15% of recruits will have a decline ($\leq -5\%$) in muscular strength and local muscle endurance.
- Individualised training strategies are required to minimise a decline in physical performance amongst the fittest recruits.
- Given that lifting and load carriage are essential and common tasks within the military an increased bias toward the development of functional muscular strength is warranted.

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