Ability of fitness testing to predict injury risk during initial tactical training: a systematic review and meta-analysis

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Title:

The ability of fitness testing to predict injury risk during initial tactical training: A systematic review and meta-analysis

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ABSTRACT

Regardless of their role within an organization, all tactical personnel require sufficient physical fitness to be able to complete daily occupational tasks safely and effectively. One challenge faced by tactical training institutions lies in the use of physical training to increase fitness, especially in less fit trainees, when physical training itself is known to contribute to injury risk. Therefore, the aims of this review were to identify studies that have investigated associations between fitness measures and injuries, critically appraise the quality of these studies, and synthesize key findings to inform tactical organizations. Twenty-seven studies were ultimately included. Mean Critical Appraisal Skills Programme score was 10.6/12 (9-12) for cohort studies and 9.5/10 (9-10) for case-control studies. A meta-analysis was performed on publications studying a timed, fixed-distance run, reporting hazard or risk ratios categorically and the number of injuries in each group. The combined risk ratio was determined to be 2.34 (95% CI 2.02-2.70). This indicates a significant increase in risk of injury during training for personnel who performed in the slowest quartile or quintile when compared to peers in the fastest quartile or quintile, which follows given this high volume of distance weight bearing activity required by tactical personnel. Muscular endurance tests, such as pushups, sit-ups and pull-ups were less conclusive in their predictive abilities. Functional strength tests were effective predictors, but only four studies reported on a measure of strength, and only two were functional measures, indicating a need for further study in this area.

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KEY MESSAGES

What is already known

- Relationships exist between a trainee’s physical fitness and their risk of suffering an injury during tactical training

What this study adds

- Quantifies the predictive ability of run time across studies, providing consensus on the topic
- Illustrates the deficiencies in research/application of strength, rather than endurance-based testing, which shows promise, but is limited in its evidence

INTRODUCTION

Tactical personnel can be defined as those individuals whose sworn duty it is to protect their country and/or community, and who may place themselves at risk for this purpose.(1) Regardless of the specific role within an organization, all tactical personnel require sufficient physical fitness to be able to complete occupational tasks safely and effectively. Common tasks may include carrying loads over distance, responding to disasters, negotiating harsh terrain, subduing human threats, evacuating casualties, and performing heavy physical labour, such as digging, chopping, and lifting.(2, 3) In order to work under these varied and often extreme physical demands, many tactical organizations assess the physical fitness of personnel against departmental standards prior to entry, during training, and at regular intervals during service.(4, 5)

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In order to prepare trainees for the rigors of their profession, trainees are frequently subjected to strenuous and regular physical training sessions aimed at increasing their fitness.(6-8) Entering this training environment may represent a sudden change in activity levels for many trainees (7, 9) which is a known contributor to injury incidence (10) along with other factors such as previous injury (11) and increased BMI.(12-15) These factors may be compounded by poor physical fitness levels at training commencement, necessitating additional physical training and consequent stress.(15, 16) As a result of these factors, initial entry trainees are known to be at an elevated risk of injury beyond that of their operational peers (17) and those who are less fit are less likely to complete training than their fitter counterparts.(18) Thus, a major challenge faced by tactical training institutions lies in the use of physical training to increase fitness, especially in less fit trainees, when physical training itself is known to contribute to injury risk.(19)

A potential approach to mitigate this risk is identification of at risk personnel based on their performance in fitness testing. This approach is supported by research suggesting a strong relationship between low levels of physical fitness and injury risk.(12-14) For example, Pope, et al.(18) found that Australian Army recruits who performed poorly in their initial 20m progressive shuttle run score were more likely to be injured during training. However, the methods and results of this research vary substantially, precluding a definitive understanding of how fitness levels during recruit training may be related to a trainee's risk of injury. For example, while several studies have reported significant association between slow run time and injury risk,(11, 15, 20, 21) Armstrong, et al. found no significant relationship between run time

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and injury in a cohort of US Navy Midshipmen.(22) Given these inconsistencies in predictive ability, the aims of this systematic review were to identify studies that have investigated associations between fitness measures and injuries in tactical trainees, critically appraise the methodological quality of these studies, and synthesize key findings to inform tactical organizations.

METHODS

Search Method

Literature databases were systematically searched using combinations of keywords (Table 1), Boolean operators, and database heading terms. The selection of keywords was initially guided by keywords used in a sample of known related articles.(23, 24) Next, filters were applied in each database, where available. In databases where these filters were not uniform with PubMed search options, the most similar filter was applied. In order to ensure that studies were applicable to current tactical training contexts and injury reporting procedures, only studies conducted within the last 20 years were included. The Defense Technical Information Center (DTIC) was also searched, as this database includes grey literature not found in traditional academic databases but is still relevant to the tactical research community. Duplicate articles were detected and removed by Endnote Software (Clarivate Analytics, Philadelphia, USA). Additional duplicates not automatically captured were removed manually (Figure 1). (Insert Figure 1 Here)

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Table 1: Keyword searches by database

Database	Filters Applied	Target variable		Exclusion Terms		Population		Outcome
PubMed	Sort By: Best Match, English Language, Publication Date 1998-2018, Human Subjects, Full text available	"Exercise Testing" OR "Physical Fitness" [Mesh] OR "Task Performance and Analysis" [Mesh] OR "Athletic Performance" [Mesh] OR "Physical Conditioning" OR "Self-Assessment" [Mesh] OR "fitness testing" OR "periodized training" OR "physical training" OR "fitness training"	NOT	"Psychometrics" [Mesh] OR"Psychological Tests" [Mesh] OR "Brain Injuries" [Mesh] OR "Amputation, Traumatic" [Mesh] OR "Limb loss"	AND	"Emergency Responders" [Mesh] OR "Military Personnel" [Mesh] OR "Police" [Mesh] OR "Sheriff" OR "Patrol Officer"OR "Law Enforcement" OR "tactical athlete" OR "police cadet" OR "trainee" OR "recruit" OR "candidate" OR "FBI"	AND	"Accidents, Occupational" [Mesh] OR "Wounds and Injuries" [Mesh] OR "injury prevention" OR "injury prediction"

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CINAHL	Abstract available, English Language	(MH "Exercise Test") OR (MH "Task Performance and Analysis") OR (MH "Resistance Training") OR (MH "Physical Fitness") OR (MH "Athletic Performance") OR (MH "Physical Conditioning") Assessment Screen Testing (MH "Self-Assessment") OR "fitness testing" OR "periodized training" OR "physical training" OR "fitness training"	NOT	(MH "Psycholometrics") OR (MH "Psychological Tests") OR (MH Brain Injuries) OR "Amputation" OR "Limb Loss"	AND	(MH "Police") OR (MH "Firefighters") OR (MH "Military Personnel") OR (MH "Military Recruits") OR (MH "Research, Military") OR (MH "Military Training") OR (MH "Military Services") OR "Sheriff" OR "Incumbent officer" OR "Patrol Officer" OR "law enforcement" OR "tactical athlete" OR "police cadet" OR "trainee" OR "recruit" OR "candidate" OR "FBI"	AND	(MH "Wounds and Injuries") OR (MH "Accidents, Occupational) OR "injury prevention" OR "injury prediction"

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SPORT Discus	1998-2018, English Abstract, Journal Article	"Fitness Testing" OR "Exercise testing" OR "Task performance and analysis" OR "Athletic Performance" OR "Physical fitness" OR “fitness screening” OR “injury screening” OR “self-assessment” OR “fitness assessment OR “physical assessment” OR “periodized training” OR “physical training” OR “fitness training”	NOT	Psychometrics OR “Psychological Test*” “Brain injur*” OR “concussion” OR “amputation” OR “limb loss”	AND	Police OR Firefighters OR Military OR Soldier OR "Military Recruit" OR "Emergency Responder" OR "Law Enforcement" OR “Sheriff” OR “Incumbent officer” OR “Patrol Officer” OR “law enforcement” OR “tactical athlete” OR “police cadet”	AND	Injur* OR Accident OR Trauma OR “injury prevention” OR “injury prediction”
Embase	1998-2018, English, Humans, Abstract available	‘Physical performance’/exp OR ‘athletic performance’/exp OR ‘fitness’/exp OR ‘occupational health’/exp OR ‘exercise test’/exp OR ‘screening test’/exp OR “fitness testing”	NOT	‘Psychometry’/exp OR ‘psychologic test’/exp OR ‘neuropsychological test’/exp OR ‘brain injury’/exp OR ‘concussion’/exp OR ‘amputation’/exp OR “limb loss”	AND	‘military phenomena’/exp OR ‘police’/exp OR ‘fire fighter’/exp OR ‘law enforcement’/exp OR ‘rescue personnel’/exp OR ‘army’/exp OR ‘soldier’/exp OR “sheriff” OR “law enforcement” OR “tactical athlete” OR	AND	‘occupational accident’/exp OR ‘accidental injury’/exp OR ‘avulsion injury’/exp OR ‘concussion’/exp OR ‘musculoskeletal injury’/exp OR ‘head and neck injury’/exp OR ‘nervous system

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						"police cadet" OR "trainee" OR "recruit" OR "candidate" OR "FBI"		injury'/exp OR 'pelvis injury'/exp OR 'sport injury'/exp OR 'soft tissue injury'/exp OR "injury prevention" OR "injury prediction"
DTIC	N/A	"Fitness testing" OR "fitness assessment" OR "exercise testing" OR "fitness screening"	NOT	Psychometric* OR "psychological test*"	AND	Police OR Officer OR Firefighter OR Soldier OR Recruit OR Trainee OR Sheriff	AND	injur* OR accident OR trauma

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Article Screening

Study eligibility criteria were applied manually through screening of study titles, abstracts and publication metadata to remove articles that were not relevant to the scope of this review (e.g. needlestick injuries, hearing injuries, radiation exposure). Following this process articles were screened against *a priori* inclusion criteria; these being: a) Study investigated a relationship between one or more direct measures of physical fitness and injury during training, b) study included data on injury or injury risk, c) study followed a tactical population, d) study was peer-reviewed, original, primary research, and e) study was published after 1998. Once all included articles had been gathered, they were compared against emerging exclusion criteria; these being a) reported on a training program or other intervention, b) did not report association between a fitness measure and injury, c) assessed medical provider access, irrespective of reason, d) single event follow-up, e) did not follow subjects through a period of training, or f) investigated heat injury.

Quality Assessment

Eligible publications identified through the literature search, screening and selection processes were then critically appraised to assess methodological quality using the Critical Appraisal Skills Programme (Middleway, Oxford, UK). Studies were independently assessed by two authors (SS & CT) and measured for agreement by a third author (RO) using Cohen's *kappa*. The CASP toolkit provides checklists to facilitate accurate and fair appraisal of studies, based on method design. Included studies were suitable for either the CASP cohort study checklist or the CASP case-control study checklist. The cohort study checklist contains 12 questions for study quality assessment. The first two questions relate to screening and the following 10 guide reviewers through the assessment of validity, relevance, methodology and result quality. The case-control checklist comprises 11 questions, the first three of which are focused on screening and the following eight questions assess validity, design effectiveness, power, and applicability.

Questions were scored on a binary scale of either ‘1’ for questions that can be answered as ‘yes’ or ‘0’ for those which are answered ‘no’ or indeterminate. To ensure validity of score reporting, authors completed CASP analysis separately. Any study with a CASP score varying by more than one point between reviewers was re-assessed by a third party. Questions seven through nine on both the Cohort Study CASP and Case-Control Study CASP were condensed into one item, as they are all closely related, and Questions seven and eight cannot be answered dichotomously. Therefore, Cohort papers were then scored out of 12 possible points and Case-Control papers were scored out of 10 possible points. The results for each study are included in Table 2.

Data Extraction

Full details of data extracted from each article can also be found in Table 2. Author, title, participants, demographics as reported, selected measures of fitness (e.g., aerobic fitness, muscle endurance, and/or muscular strength/power), injury definition, outcome measure, statistical analysis, key results, and CASP score were included. For brevity, only those results meeting statistical significance were included. Data extracted for meta-analysis were also

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included in Table 2. However, all findings reported in studies meeting selection criteria were included, regardless of statistical significance.

Meta-Analysis

Studies were selected for meta-analysis based on the following criteria: a) study investigated a timed running event and injury risk, b) data were reported categorically, and c) the total number of injuries in each group were obtainable from published data. A random-effects model was used to account for differences between tactical subpopulations, run lengths and sample sizes. Studies were automatically weighted by sample size and confidence interval precision by Revman 5.1 (Cochrane Institute, London, UK). To account for differences in categorization (quartile or quintile), only the fastest and slowest group from each study were included. Final aggregate risk ratio was determined by Mantel-Haenszel analysis of event (injury) incidence difference between fastest and slowest groups. Manual sensitivity analysis showed the study Blacker, et al.(25) accounted for 61% of overall heterogeneity and therefore was excluded from final analysis. Ultimately, seven studies were included.(10, 11, 15, 21, 26-28)

RESULTS

The results of search, screening, and selection processes are documented in the PRISMA(29) flow diagram (Figure 1). A total of 1199 publications were captured in the initial search. 135 duplicates were removed automatically, and a further 35 duplicates were removed manually. Of the remaining 1029 articles, 971 did not meet title or abstract relevance based on the initial research question. 58 abstracts were then assessed further based on formal inclusion criteria.

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The final 58 publications were screened by full text against study exclusion criteria ultimately leaving 27 publications for review.

Critical Appraisal

The mean CASP score was 10.6/12±0.96 (range 9-12) for the cohort studies and 9.5/10±0.7 (range 9-10) for the case-control studies. Of the cohort studies, five studies scored 12/12, eight scored 11/12, eight scored 10/12, and four scored 9/12 (See Table 2). Of the case control studies, one scored 10/10 (30), and one study scored 9/10 (22). The level of agreement between the two authors, as measured by Cohen's kappa, (k= 0.750) was considered a 'substantial agreement'.(31)

Research Metadata

Study Design

Twenty-five of the studies were of a retrospective cohort design with the remaining two studies being of a case-control design.(22, 30) The United States accounted for the largest number of studies, with 15. Three studies were from Finland,(32-34) two studies originated from the United Kingdom,(20, 35) two from Israel,(36, 37) two from Australia,(38, 39) and two from Switzerland.(40, 41) One study was from Malta.(42)

Demographics

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11 studies included both male and female participants. Eight articles followed males only,(5, 14, 28, 34, 35, 37, 41, 43) five followed females only,(13, 14, 21, 27, 36) and three studies did not report sexes of their participants.(38-40)

Three tactical subpopulations were represented; the largest being military populations, with 24 articles. Two studies followed Australian Police trainees,(38, 39) and one study followed US Federal Bureau of Investigation trainees.(10)

Injury Definition

The evaluated injuries and nomenclature varied substantially across studies. Eleven studies included any musculoskeletal injury, while the other publications reported the following injury definitions: Seven studies reported lower limb stress fractures,(14, 21, 22, 27, 28, 32, 37), with one specifically considering femoral neck stress fractures.(30) Two articles recorded any injury, without further description.(10, 16) Two articles considered any musculoskeletal injury requiring hospitalisation,(13, 32) two articles considered musculoskeletal injury requiring referral,(14, 20) one article was specific to time loss injury,(11) and one article reported any lower limb injury.(42)

Fitness Assessments and Predictive Ability

Aerobic Fitness

Results of the Meta-Analysis and the forest plot can be found in Figure 2. The aggregate risk ratio was determined to be 2.34 (95% CI 2.02-2.70), indicating a significant increase in risk of

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injury during training for personnel who perform in the bottom quartile or quintile when compared to peers in the fastest quartile or quintile. (Insert Figure 2 Here) Of all studies reporting any measure of aerobic fitness, 19 of 21 reported a significant finding. Of the two studies that did not, one study was a smaller, case-control design (22) and the other was investigating femoral neck stress fractures exclusively.(30)

Muscular Fitness

A total of ten studies (5, 10, 11, 16, 22, 30, 33, 34, 44, 45) investigated relationships between pushups and injury. Four (5, 11, 22, 33, 44) reported no significant relationship between timed pushup count and injury risk during training. Of these, one limited their definition of injury to those requiring hospitalization.(32) Three studies considered only lower limb injuries, and yet all reported a significant finding.(22, 30, 45) All others did not anatomically limit their definitions. Of the studies reporting a significant finding, two found their results were limited to males only (10, 22), another found pushups were predictive only of acute injury, and not overuse injury (34) and one was of a smaller, case-control design.(30)

Thirteen studies (5, 10, 11, 16, 22, 27, 28, 30, 33, 41, 43-45) investigated a sit-up or crunch test. Of these, eight found no significant relationship between timed sit-up or crunch count and injury risk during training. Two studies favoring sit-up count had very specific definitions of injury; one investigated femoral neck stress fractures (30) and another investigated only injuries resulting in time lost from training.(11) One study found statistically significant predictive ability of the situp test in males, but not females.(16)

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Three studies reported no significant relationship between timed pullup or chin-up count and injury risk during training.(27, 34, 43) All studies investigating pullups or chin-ups had a broad definition of injury; any acute or overuse musculoskeletal injury was considered. While only one study suggested pullup count was an effective predictor,(20) it did report a significant result for both males and females. One study reporting no relationship between pullup count and injury during training investigated a female only cohort.(27)

Muscular Strength

Four studies reported on one or more measures of strength.(16, 25, 37, 46) Two of the studies found significant relationships between grip strength(46) and leg press strength(37) and injury risk during training. The studies that did not find a significant result used dynamometer testing rather than functional test methods.(16, 25)

Muscular Power

Two studies investigated a measure of muscular power (25, 47). One used an external load (dynamic lift strength in a 1 rep max movement) and another used vertical jump height. Both studies reported a statically significant finding.

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Table 2, Data extraction table

Title/ Authors	Participants	Fitness Measures	Injury Reporting	Follow Up	Results†	CASP Score
Armstrong et al. 2004 Stress Fracture Injury in Young Military Men and Women	US Naval Academy Midshipmen Cases (*n*=31) Age (F): 18.5±0.17 years Age (M): 18.9±0.21 years Height (F): 163.9±1.74 cm Height (M): 181.6±1.97 cm Weight (F): 62.9±2.31 kg Weight (M): 78.3±2.01 kg BMI (F): 23.0±0.63 BMI (M): 23.8±0.54 Controls (*n*= 31) Age (F): 18.4±0.17 years Age (M): 19.3±0.21 years Height (F): 166.2±1.74 cm Height (M): 177.2±1.97 cm Weight (F): 65.0±2.31 kg Weight (M): 76.8±2.01 kg BMI (F): 23.5±0.63 BMI (M): 24.5±0.54	Initial Strength Test: 1 mile run Max pushups in 2 mins Max Sit ups in 2 mins	Lower extremity stress fracture: Tibial (n=43) Metatarsal (n=5) Femoral (n=3) Fibular (n=3) Other (n=4)	-	Male cases completed fewer pushups Cases: 59±4 Controls: 72±4	9/10 Case-Control
Kupferer et. al. 2014 Femoral neck stress fracture in Air Force basic trainees	US Air Force Initial Entry Trainees *n* = 47 cases and 94 controls	US Air Force Fitness Assessment T1: Max pushups in 1 min T2: Max sit-ups in 1 min T3: 1.5 mile run for time	Femoral Neck Stress Fracture 47 cases	8.5 weeks	T1: controls completed more reps OR 0.58 (0.38-0.88) T3: cases had slower run times OR 1.49(1.19-186) Male findings were especially significant OR 3.24 (1.16-9.04)	10/10 Case-control
Bedno et al. 2013 Effect of pre-accession physical fitness on training injuries among US Army recruits	Male US Army Initial Entry trainees *n*=8456 Age 18-19: 784 Age 20-24: 869 Age >25: 292 BMI category underweight: 56	Harvard Step Test: 120 steps per minute onto a 16 inch platform for 5 minutes	Outpatient presentation during training for musculoskeletal pain, a sprain or strain, arthropathy, bone stress injury or tendonopathy	90 days	HR 1.31 (1.07-1.61) for test failure	10/12 Cohort

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	BMI category normal: 791 BMI category overweight: 722 BMI category obese: 376	Scored as pass/fail; those who completed all 5 minutes at pace passed				
Blacker et al. 2008 Risk Factors for Training Injuries among British Army Recruits	British Army Initial Recruit Trainees *n*=13417 *n*=11937 males *n*=1480 females Age: 20.5±3.2 years Height: 175±8cm Weight: 70±10kgs BMI: 23±2	T1: 2.4km run T2: 20m shuttle runs to failure T3: Max Chin-ups (heaves) T4: 4kg ammunition box hold for 4mins T5: IKD measurement of back extension strength T6: Static lift strength T7: Dynamic lift strength	Training related acute or overuse injury resulting in referral for remedial instruction	183 days	T1: QT1: (fastest) HR 1.00 QT2: HR 1.66 (1.18-2.34) QT3: 2.44 (1.76-3.37) QT4: 3.56 (2.61-4.85) QT5: (slowest) 6.25 (4.66-8.39) T2: QT1: (fewest repeats) HR 1.00 QT2: HR 0.63 (0.47–0.76) QT3: HR 0.43 (0.33–0.55) QT4: HR 0.33 (0.24–0.44) QT5: (most repeats) HR 0.20 (0.14–0.29) T3: QT1: (fewest reps) HR 1.00 QT2: HR 0.56 (0.46–0.69) QT3: HR 0.44 (0.35–0.55) QT4: HR 0.43 (0.35–0.52) QT5: (most reps) HR 0.30 (0.24–0.38) T4: QT1: (shortest hold) HR 1.00 QT2: HR 0.50 (0.38–0.66) QT4: HR 0.42 (0.33–0.55) QT5: HR 0.47 (0.37–0.60) T5: QT1: (weakest) HR 1.00 QT2: HR 0.57 (0.47–0.70) QT3: HR 0.38 (0.31–0.48) QT4: HR 0.46 (0.38–0.58) QT5: HR 0.37 (0.30–0.47) T6: QT1: (lowest) HR 1.00	12/12 Cohort

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					QT2: HR 0.61 (0.50–0.75) QT3: HR 0.48 (0.39–0.60) QT4: HR 0.48 (0.39–0.60) QT5: (highest) HR 0.38 (0.30–0.48) T7: QT1: (lowest) HR 1.00 QT2: HR 0.52 (0.42–0.66) QT3: HR 0.37 (0.28–0.47) QT4: HR 0.45 (0.38–0.55) QT5: HR 0.41 (0.33–0.51)	
Cowan et al. 2012 Step Test Performance and Risk of Stress Fractures Among Female Army Trainees	Female US Army initial entry trainees *n*=1568 Age 18-19: 746 Age 20-24: 588 Age >25: 234 BMI category underweight: 73 BMI category normal: 1032 BMI category overweight: 428 BMI category obese: 35	Harvard Step Test: 120 steps per minute onto a 16 inch platform for 5 minutes Scored as pass/fail; those who completed all 5 minutes at pace passed	64.2% experienced ≥1 injury 7.0% stress fractures 4.3% equivocal stress fracture 57.7% MSK injury 98% of those who had a stress fracture also had an MSK injury	180 days	Stress fracture: IRR 1.76 (1.18-2.63) MSK injury: IRR 1.35 (1.16-1.57)	9/12 Cohort
Grier et. al. 2011 Risk Factors for Injuries in the US Army Ordnance School	US Army Advanced Individual Training Recruits *n*=4255 *n*=3757 males *n*=498 females Age 17-19: 2309 Age 20-24: 1495 Age >25: 451	US Army Physical Fitness Test T1: 2 minute max pushups T2: 2 minutes max sit-ups T3: 2 mile run for time	Time-loss injury: injury of any type listed by the medical provider the trainee presented to that required limited duty or restriction to quarters for one or more days	10, 9, 13, 16, or 12 weeks, specific to each career field	Male T2: QR1: (most reps) HR 1.00 QR2: HR 1.21 (1.01-1.46) QR3: HR 1.35 (1.12-1.62) QR4: (fewest reps) HR 1.23 (1.02.-1.48) Male T3: QR1 (fastest): HR 1.00 QR4 (slowest): HR 1.41 (1.18-1.69) Female T3: QR1 (fastest): HR 1.00 QR2: HR 1.58 (1.09-2.30) QR4 (slowest): HR 2.17 (1.50-3.14)	9/12 Cohort
Hall 2017 Relationship between 1.5 mile run time, injury	Male British Army initial entry training recruits *n*=3446	Timed 1.5-mile run	591 MSK injuries were reported; 63% were acute 78% were lower limb	June 2009-June 2011	0-20th percentile (fastest): RR 1.00 21-40th percentile (562-590 sec): RR 1.25 (0.96-1.64)	11/12 Cohort

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risk and training outcome in British Army Recruits			42% were reported to be caused by running 71% occured in the first 6 weeks		41-60th percentile: RR 1.38 (1.06-1.81) 61-80th percentile: RR 1.60 (1.24-2.06) 81-90th percentile: RR 1.96 (1.48-2.60) 91-100th percentile (slowest): RR 2.37 (1.82-3.09)	
Hoffman et. al. 1999 The Effect of Leg Strength on the Incidence of Lower Extremity Overuse injuries during Military Training	Israeli Air Force Basic Trainees *n*=136 male recruits Age: 18±0.0 years Height: 176±7cm Weight: 66.7±12.0kgs Body fat percentage: 13.6±5.8	T1: 1 Repetition Max leg press T2: 2km run for time	Stress fracture and related events: 58 clinical visits suggestive of overuse injury 32 episodes of limited duty 12 diagnoses of stress fracture	9 weeks	Means were compared to results 1SD below means T1: RR 4.7 (1.7-13.6) 1 Repetition Max leg press per kg of body weight: RR 5.2 (1.8-14.7) T2: RR 1.9 (95%CI 0.6-6.6)	9/12 Cohort
Jones et. al. 2017 Impact of physical fitness and body composition on injury risk among active young adults: A study of Army trainees	US Army initial entry trainees *n*=184670 *n*=143398 males *n*=41727 females Age (M): 22.6±4.9 Age (F): 22.3±4.8 Height (M): 176±6cm Height (F): 162±6cm Weight (M): 77.8±13.2 Weight (F): 61.8±8.6 BMI (M): 25.1±3.7 BMI (F): 23.3±2.7	US Army Physical Fitness Test T1: 2 minute max pushups T2: 2 minute max sit-ups T3: 2 mile run for time	Any acute or overuse MSK injury reported during the training period	All 10 week training periods from Oct 2009 to Sept 2012	Male T3: QT1: 1.0 QT2: RR 1.3 (1.2-1.3) QT3: RR 1.5 (1.4-1.5) QT4: RR 1.8 (1.7-1.8) QT5: RR 2.5 (2.4-2.5) Female T3: QT1: (fastest) RR 1.0 QT2: RR 1.3 (1.3-1.4) QT3: RR 1.5 (1.4-1.5) QT4: RR 1.7 (1.6-1.8) QT5: (slowest) RR 2.1 (2.0-2.2)	10/12 Cohort
Knapik, et. al. 2011 Injury rates and injury risk factors among Federal Bureau of Investigation new agent trainees	Federal Bureau of Investigation new agent trainees *n*=531 *n*=426 males *n*=105 females	Physical Fitness Test T1: sit-ups T2: push-ups T3: 300-meter sprint T4: 1.5 mile run	Any physical damage to the body requiring medical care or medical compensation at one or more times during training	1 year	Male T3: QR4: HR 1.71 (1.03-2.84) Female T3: Tertile 3: HR 2.23 (1.06-4.70) Male T4: QR4: HR 2.06 (1.30-2.75) Female T4:	12/12 Cohort

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					Tertile 3: HR 1.95 (1.00-3.80)	
Knapik, et. al. 2001 Risk factors for training-related injuries among men and women in basic combat training	US Army Initial Entry Trainees *n*=1208 756 males 452 females Age (M): 21.5±3.6 Age (F): 21.3±3.8 Height (M): 176±7.5cm Height (F): 164.3±6.5cm Weight (M): 75.3±13.3kg Weight (F): 62.2±10.6kg BMI (M): 24.2±3.8 BMI (F): 23.0±3.2	US Army Physical Fitness Test T1: 2 minute max pushups T2: 2 minutes max sit-ups T3: 2 mile run for time Physiological Tests T4: PeakVO2 treadmill	All Overuse Injuries or Traumatic Injuries Time-loss injury Lower extremity injuries	8 weeks	Male T1: QR3: RR 1.8 (1.2–2.8) QR4: RR1.8 (1.2–2.8) Male T2: QR4: RR 1.6 (1.0–2.4) Male T3: QR4: RR 1.6 (1.0-2.4) Male T4: Lowest tertile absolute VO2Peak: RR 2.1(1.0-4.5) Lowest tertile relative VO2Peak: RR 1.9(1.0-3.7) Female T1: QR2: 1.6(1.1–2.5) QR3: 1.6(1.1–2.3) QR4: 1.6(1.1–2.4) Female T3: QR3: 1.6 (1.0–2.3) QR4: 1.9 (1.2–2.8) Lowest tertile absolute VO2Peak: RR 1.9 (1.1-3.2) Lowest tertile relative VO2Peak: RR 1.9 (1.1-3.4)	10/12 Cohort
Kodesh et. al. 2015 Examination of the Effectiveness of Predictors for Musculoskeletal Injuries in Female Soldiers	Female Combat Fitness instructor Course Trainees (Israel Defense Force) *n* = 158 Age: 18.1-20.2 years (median 19.0) Height: 146-181cm (median 1.64) Weight: 43-82kg (median 56) BMI: 16.1-32.0 (median 20.8)	2km run for time	145 injuries 80% lower extremity MSK 84% categorized as overuse 37 soldiers lost at least 2 days of training from their injury	3 months	OR: 1.007 (95% CI 1.001-1.014)	10/12 Cohort

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Krauss et. al. **2017** Excess Stress Fractures, Musculoskeletal Injuries, and Health Care Utilization Among Unfit and Overweight Female Army Trainees	Female US Army Initial Entry Trainees *n* = 1900 Age 18-19: 756 Age 20-24: 596 Age ≥25: 233 BMI category underweight: 76 BMI category normal: 1039 BMI category overweight: 432 BMI category obese: 38	Harvard Step Test 120 steps per minute onto a 16 inch platform for 5 minutes Scored as pass/fail; those who completed all 5 minutes at pace passed	MSK injury requiring healthcare utilization: Medical encounters resulting in musculoskeletal injury diagnoses and all physical therapy visits	6 months	IRR 1.32 (95% CI, 1.14-1.53)	11/12 Cohort
Lisman et. al. **2013** Functional movement screen and aerobic fitness predict injuries in military training	Male US Marine Corps Officer Candidate School Trainees *n* = 6wk course: 447 and 10 week course: 427 Age: 22.4± 2.7	US Marine Corps Physical Fitness Test Pull-ups to exhaustion Max abdominal crunches in 2 mins 3 mile run for time	Categorical MSK injuries Traumatic or Overuse	6 weeks 10 weeks	T3: (>20.5 mins to complete) OR 1.72 (95% CI 1.29–2.31) (p<0.001)	11/12 Cohort
Mattila, Kuronen, et. al. **2007** Nature and risk factors of injury hospitalization in young adults: a follow-up of 135,987 military conscripts	Finnish Initial Entry Trainees *n* = 135987 BMI <25: 79% of trainees BMI 25-30: 17% of trainees BMI >30: 4% of trainees 133943 men 2044 women	Max pushups in 1 min Max distance standing long jump Max sit-ups in 1 min Max back lifts in min Pull-ups to exhaustion 12 min run for distance (Cooper's test)	Hospitalization for lower limb injury 6059 hospitalizations for injury 2695 (57%) were joint sprains/ dislocations	6-12 months	Aggregate fitness score: Poor: OR 1.0 (referent) Average: OR 1.0 (95% CI 0.9–1.1) Good: 1.2 (95% CI 1.1–1.3) Excellent: 1.3 (95% CI 1.1–1.4) Aerobic Fitness: (Coopers test) (overuse injury only) Poor: 1.0 (referent) Average: 0.9 (95% CI 0.8–1.1) Good: 1.0 (95% CI 0.9–1.2) Excellent: 1.3 (95% CI 1.1–1.5)	9/12 Cohort
Mattila, Niva, et. al. **2007** Risk Factors for Bone Stress Injuries: A	Finnish Initial Entry Trainees *n* = 152095 BMI <20: 17% of trainees BMI 20–25: 58% of trainees BMI >25: 25% of trainees	Max pushups in 1 min Max distance standing long jump Max sit-ups in 1 min Max back lifts in min Pull-ups to exhaustion	Bone stress injuries of the pelvis, hip, thigh, or knee 319 cases	6-12 months	Aerobic Fitness: (Coopers test) QR1: 1 (referent) QR2: 1.0 (0.7–1.6) QR3: 1.3 (0.9–2.0)	9/12 Cohort

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Follow-up Study of 102,515 Person-Years	17-29 years (median 20) 149750 men 2345 women	12 min run for distance (Cooper's test)			Q4: 1.3 (0.8–2.0) Aggregate Strength score: QR1: 1 (referent) QR2: 0.8 (0.5–1.4) QR3: 1.2 (0.8–1.9) QR4: 1.4 (0.7–1.9)	
Nye et. al. 2016 Description and Rate of Musculoskeletal Injuries in Air Force Basic Military Trainees, 2012-2014	US Air Force basic military trainees *n* = 67525	PFT (Physical fitness test) Push up count Sit up count 1.5 mile run time	12.5% injured with 1 or more injuries n = 8448 78.4% n=9147 involved the lower extremity	8.5 weeks	Push-up count p=<0.001 Sit-up count p=<0.001 1.5 mile run p=<0.001	11/12 Cohort
Orr, et. al. 2016 Leg Power As an Indicator of Risk of Injury or Illness in Police Recruits	Australian Police recruits *n* = 1021	Vertical jump height	Injuries alone 15% (n = 158)	12 weeks	Correlation between Vertical Jump height and injury and illness prevalence were p=0.003 and p=0.001 respectively	10/12 Cohort
Orr, et. al. 2017 Grip Strength and Its Relationship to Police Recruit Task Performance and Injury Risk: A Retrospective Cohort Study	Police recruits undergoing full-time training at a police college in Australia *n* = 169 No demographic information was available	Grip strength measured using a handgrip dynamometer. Maximum grip strength of right and left hands was measured to the nearest kilogram.	An injury was reported in 25.4% (n=43) of recruits Injury data was collected during the training period. This was done from the reporting protocol by using a standard accident and incident form No information was provided regarding injury type, site or severity	12 weeks	Mean grip Left (kg) No injury 42.80 ± 8.23 Injury 39.28 ± 8.92 r = -0.181 (p = 0.018)	10/12 Cohort

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Psaila et. al. 2017 Risk factors for lower leg, ankle and foot injuries during basic military training in the Maltese Armed Forces	Maltese Armed Services Initial Entry Trainees *n* = 127 114 males 13 females Mean age: 21.7 (2.4) Mean BMI: 24.8	Physical Fitness Test: Max push-ups in 2 minutes Max sit-ups in 2 minutes 1 mile run for time	Lower limb injuries Most common injuries per body part were: medial tibial stress syndrome in the leg, acute lateral ankle sprain in the ankle and heel fat pad contusion in the foot 45 injuries (incidence: 0.204 injuries/100 days)	135 days	Pre-Basic Military Training fitness test scores were associated with injury risk during BMT (Mann-Whitney U = 1226, p = 0.039)	11/12 Cohort
Rauh et. al. 2006 Epidemiology of stress fracture and lower-extremity overuse injury in female recruits	Female US Marine Corps Initial Entry Trainees *n* = 824 Age 17-19: 738 Age ≥20: 86 BMI category underweight: 63 BMI category normal: 737 BMI category overweight: 20	US Marine Corps Physical Fitness Test Pull-ups to exhaustion Max abdominal crunches in 2 mins 3 mile run for time	Lower-extremity stress fracture Non–stress fracture overuse injuries 399 cases	13 weeks	Run time, Stress Fracture QR1 1.0 QR2 1.4 (0.5, 3.9) QR3 1.1 (0.4, 3.2) QR4 3.3 (1.4, 8.1)	11/12 Cohort
Sefton et. al. 2016 Prediction of Injuries and Injury Types in Army Basic Training, Infantry, Armor, and Cavalry Trainees Using a Common Fitness Screen	US Army Initial Entry Trainees *n* = 1788 Age: 20.48±3.4	1-1-1 Test Max pushups in 1 min Max sit-ups in 1 min 1 mile run for time	Acute or overuse MSK injury 308 traumatic injuries 222 overuse injuries	9-16 weeks	Ln Run Time: Estimate: 1.972 (p<0.001)	12/12 Cohort
Shaffer et. al. 1999 Use of simple measures of physical activity to predict stress fractures in young men undergoing a rigorous physical training program	US Marine Corps Initial Entry Trainees *n* = Phase 1: 1286 and Phase 2 1078 Phase 1 Age: 18.9±2.3 Phase 2 Age: 18.4 ± 1.4	Aerobic Fitness Assessment 1.5 mile run for time	Lower extremity stress fractures 52 cases 56 total injuries tibia (46.4%) foot (39.3%) fibula (5.3%t) heel (5.3%) femur (1.8%) pelvis (1.8%)	12 weeks	Initial Strength Test by 1.5 miles run time QR1: 1.0 (referent) QR2: 0.87 (0.27-2.82) QR3: 1.72 (0.65-4.6) QR4: 3.11 (1.26-7.66)	10/12 Cohort

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Shaffer et. al. **2006** Predictors of stress fracture susceptibility in young female recruits	Female Marine Corps Recruits *n* = 2962 Aged 17 to 33 years Weight: 58.17kg BMI: 21.67	Aerobic Fitness Testing 0.75 or 1 mile run, depending on recruiting station	Lower Extremity stress Fractures 152 cases (5.1%) 181 total injuries tibia (24.9%) metatarsals (22.1%) pelvis (21.6%) femur (19.9%)	12 weeks	Run Time Overall Stress Fracture AOR (95% CI) QR1: 1.00 QR2: 1.21 (0.5-2.1) QR3: 3.41 (1.9-6.1) QR4: 3.54 (2.0-6.3)	11/12 Cohort
Taanila et. al. **2015** Risk factors of acute and overuse musculoskeletal injuries among young conscripts: A population-based cohort study	Finnish Army Initial Entry Trainees *n* = 1411 Median Age: 19 Median BMI: 22.6 (signals) 23.3 (mortars) 23.4 (anti-tank) 23.6 (engineering)	T1: Max pushups in 1 min T2: Max distance standing long jump T3: Max sit-ups in 1 min T4: Max back lifts in min T5: Pull-ups to exhaustion T6: 12 min run for distance Coopers Test T7: Muscle Fitness index (sum of T1-5) T8: Physical Fitness Index (T6+100xT7/200) Graded in categories: poor, fair good, good, and excellent	Acute or overuse MSK injury 550 acute injuries (n = 27%) 1351 overuse injuries (n = 51%) 1411 cases	180 days	Acute Injury T1: Poor (<22) HR1.4 (1.1-1.9) T2: Poor (<2.00m) HR1.4 (1.0-2.0) T7: Good (9-12 points) HR1.5 (1.0-2.2) Poor (0-4 points) HR1.6 (1.1-2.4) Overuse injury T1: Poor (<22) HR = 1.5 (1.2-1.8) T2: Poor (<2.00m) HR = 1.6 (1.2-2.0) T4: Fair good (>40) HR = 1.3 (1.1-1.5) Poor (<40) HR = 1.9 (1.5-2.4) T6: Fair good(>2200m) HR = 1. 3(1.1-1.5) Poor (<2200m) HR = 1.8 (1.5-2.2) T7: Fair good (5-8 points) HR = 1.5 (1.1-1.9) Poor (0-4 points) HR = 1.7 (1.3-2.3) T8: Fair good (13.00-16.99) HR = 1.3 (1.1-1.5) Poor (<13.00) HR = 1.8 (1.5-2.2)	11/12 Cohort

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Wunderlin et. al. 2015 Trunk muscle strength tests to predict injuries, attrition and military ability in soldiers	Swiss Army fusilier company recruits (n = 230) Age: 20.4±1.2 height: 177.8±6.4 cm Weight: 73.7±11.8 BMI: 23.3±3.2	T1: Max sit-ups in 2 mins T2: TMS Front plank position with alternating leg elevations at a 1Hz rhythm	Acute or overuse MSK injury 111 Acute injuries 81 Overuse injuries 192 total 126 cases	13 weeks	T2: Total injury: 0.58 total AUC (*p*=0.033 ROC analysis) Acute injury: 0.58 total AUC (*p*=0.035 ROC analysis)	11/12 Cohort
Wyss et. al. 2012 The Swiss Army physical fitness test battery predicts risk of overuse injuries among recruits	4 Groups of Swiss Army Career-Specific Initial Entry Trainees *n* = 459 Rescue Technicians *n*=131 Armoured Infantry *n*=145 Fusilier Infantry *n*=107 Reconnaissance Infantry *n*=76	T1: Standing Long jump T2: Seated Shot Put T3: Trunk Muscle Strength Test T4: One-leg Standing Test T5: Progressive Endurance Run	234 total injuries 64.5% Overuse origin	18 weeks	Rescue Technician: T3: 2.53 (1.04-6.15) *p*=0.025 T4: 2.24 (1.22-4.12) *p*=0.011 Armoured Infantry: T3: 1.63 (1.04-2.56) *p*=0.028 T4: 2.20 (1.39-3.49) *p*<0.0001 Fusilier Infantry: T1: 1.81 (1.12-2.92) *p*=0.013 T3: 2.19 (1.31-3.66) *p*=0.001 T4: 2.44 (1.44-4.14) *p*<0.0001 T5: 1.81 (1.12-2.92) Reconnaissance Infantry: T3: 2.06 (1.25-3.40) *p*=0.005	10/12 Cohort

† All Confidence intervals reported are at the 95% level unless otherwise noted

Legend:
US: United States
T1,2,3,n: Test 1,2,3,n
OR: Odds Ratio
BMI: Body Mass Index
HR: Hazard Ratio
IKD: Isokinetic Dynamometer
QT: Quintile
MSK: Musculoskeletal
RR: Risk Ratio

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CI: Confidence Interval
QR: Quartile
IRR: Incidence Rate Ratio
AOR: Adjusted Odds Ratio

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DISCUSSION

The aim of this study was to identify, appraise and synthesize the findings of studies that investigated relationships between initial tactical training fitness assessments and injuries sustained during that training. Twenty-seven studies were included and were generally of high quality due to the observational method of study designs. While some fitness tests were more conclusive than others in predictive ability effectiveness, our results indicate a more fit tactical trainee is less likely to experience injury during initial training.

While aerobic fitness testing methods were highly variable across studies, cross-study agreement was greatest among this test type. Run distances reported were as low as 1km,(21) or 12 minutes in duration,(33, 34, 44) indicating that greater distance tests, such as the US Marine Corps training's three mile test, are not necessarily better predictors of fitness. Therefore, assessors could consider measuring trainees over shorter distances, reducing total training load and thereby reducing injury risk (48). There may also be benefit from time-to-exhaustion testing, which can account for variations in motivation while still reducing overall training volume.(49) It should also be noted that extensive previous research in operational units has indicated regular load carriage activity is essential in acclimating individuals to tolerate load carriage for extended periods of time,(50) and yet no studies have investigated a load carriage test in their battery for initial trainees. Weight bearing activity of all degrees of load and over varying distances is inescapable in both training and operational tactical contexts,(48, 51) and the overwhelming percentage of lower-limb and overuse injuries in tactical personnel is reflective of this reality.(13, 22, 30, 40, 51) Because timed distance run events rely on aerobic capacity in weight bearing over a distance, this certainly contributes to the definitiveness of their predictive ability.

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Muscular fitness tests (pushups, sit-ups, pull-ups and chin-ups) are less clear in their predictive ability; ten studies investigated a pushup test,(5, 10, 11, 16, 22, 30, 33, 34, 44, 45) with an almost even split. Six identified effective predictive ability,(10, 16, 22, 30, 34, 45) and four did not (5, 11, 22, 33, 44). It is worth noting that three of the studies reporting a significant finding (22, 30, 45) investigated lower limb injuries in military trainees using similar protocols, indicating pushup tests of this design, in this population, may be a more global measure of fitness and not simply a strict measure of upper body muscular capacity. The most robust of those three studies(45) reported a mean pushup count of 13.5±8.6 for injured female, 33.4±12.7 for injured males, 15.7±8.9 for uninjured females and 36.6±12.3 for uninjured males.

While eight of the 12 studies considering a sit-up test did not report a significant finding, one of the four studies favouring a sit-up test had very large sample size (n=67525).(45) There were no clear consistencies between those studies that found a significant relationship between sit-ups or crunches and injury and those that did not. Both military and police populations are represented in the studies finding a significant conclusion. Protocols for sit-up and crunch tests varied widely however, possibly obscuring the effectiveness of the general intent to target gross trunk muscle capability. Drawing a definitive conclusion on the effectiveness of pullup or chin-up tests is limited due to the small number of studies including these tests in their investigations.

Functional strength tests were effective and reported large differences in risk between highest and lowest performers.(37, 46) However, there is limited data from which a definitive conclusion can be drawn, especially given that isokinetic dynamometer testing was less effective in predicting injuries.(16, 25) It may be possible that isometric (grip strength) isotonic (leg press) strength are more sensitive to

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performance or injury than isokinetic strength. Further study should focus on the design, implementation and effectiveness of field expedient measures of functional strength.

Muscular Power tests were effective predictors as well in both a military (25) and a law enforcement context.(47) Although both tests (a vertical jump and dynamic 1 rep max lift) reached statistical significance, these results are too limited to draw a definitive conclusion, and further research in this area is necessary.

While it has been suggested that changes to the variables and methods used to predict injury must change in order for injury screening tools to be effective,(52) the ultimate value of fitness testing in the tactical environment is in the assessment's specificity to the operational or training context it is evaluating. The results of our meta-analysis confirm this notion; because military personnel are often required to perform running, marching and load carriage activities on a regular basis, a test that taxes aerobic capacity and the ability to bear weight over time appears to be sufficient in predicting injury without additional modelling.

Differences in approaches to fitness testing should also be noted. In this review the intent of fitness testing was not to predict occupational performance, but to determine whether trainees were more likely to sustain an injury when training itself was the occupational requirement. As such, once training commences, the approach to fitness testing can, and should differ. The intent of training for tactical organizations is to ensure that training prepares personnel for operational duty in real-world scenarios. On this basis, conditioning should focus on operational requirements rather than training for a test which, while predictive of survivability of training at the onset, may not best facilitate the training intent (operational readiness). An example of how this malalignment in physical training occurs was

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highlighted by Orr, et al. (53) where an ankle injury was caused by excessive pushups; a training cadet had performed excessive pushups the night before an obstacle course drill, in order to improve pushup ability for their assessment, and was subsequently too fatigued to properly lower from a 12-foot wall, landing badly and ultimately causing their ankle injury. This phenomenon may be further highlighted in the predictive ability of run times to predict a wide variety of both acute and overuse injuries, not just those of the lower limb. It is likely that those trainees with faster run times experience less metabolic stress during a given training event and are thereby less reliant on their passive structures to accommodate forces experienced during training, and so ultimately are less likely to become injured.

Study Populations

Military initial entry trainees represented the largest subpopulation of tactical personnel in the studies selected for this review and substantial differences existed between their characteristics; national origin, branch of service and subsequent job tasks, and average age and education level serve as examples. Some, or all, of these factors could have an effect on injury type, incidence, severity and recovery, which may confound our findings. In some of the studies included in this review,(38, 39) organizations required additional privacy measures for study participants, limiting which data could be released publicly in the study manuscripts, further obstructing cross-study comparison. Differences between trainee populations and operational personnel should also be noted; previous research has indicated that personnel undergoing training are more susceptible to injury than their operational peers,(7, 9, 54) and the job tasks required of different professions not only between tactical fields (emergency responders vs. military vs. firefighting) but within a given profession (such as different military assignments)(11, 40) can also affect the nature of injuries sustained. Perhaps more importantly, the end goals of operational and training personnel are fundamentally different; during training the objective is to complete training and operational personnel are required to complete operational tasks. Therefore, the findings of this review may not generalize beyond training populations.

Fitness Testing

Tactical fitness assessments are often required to be field expedient and completed with a minimum of personnel, training and resources, potentially under adverse conditions and must also be cost and time effective, even when large numbers of personnel are evaluated.(55) Given these demands, most fitness tests in this review consisted of easily implemented indirect measures of muscular fitness and metabolic capacity; body-weight exercises (pushups, sit-ups, pull-ups) and timed distance runs, ranging anywhere from 1.1-4.8km. However, these indirect means of assessment were not always consistent in their predicative ability; it is likely that different classifications or qualities of injury may be more or less sensitive to prediction by the above common fitness measures, and differences in test administration (e.g., definition of technique during muscular fitness assessments) may also play a role in the inconsistency of study outcomes. However, the necessary requirement for military personnel, the primary population of this review, to engage in weight bearing activity across distances on a regular basis likely contributes to the substantial agreement in studies investigating a timed, fixed distance running event,(48, 51) and the reasoning behind the selection of endurance, rather than strength or power tests. Even within studies that report similar definitions of injury, common injury classification systems are now undergoing scrutiny for validity and accuracy, as well as improvement in communication, as a number of injury classification systems do not account for various clinically relevant features of soft tissue injury.(56) Improvements in this domain, and further research within the tactical community that applies improved injury classification systems may lead to more consistent outcomes in injury prediction studies using fitness tests.

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Finally, the populations included studies followed are known for underreporting their injuries, especially when the reporting mechanism is not point of care.(57, 58) Pope, et al.(59) identified this phenomenon in a comparison of reporting systems, concluding that between 80 and 90% of all injuries sustained by Australian Army personnel that may require healthcare intervention are not reported to a collection database when compared to a 'point of care' injury reporting system often used in research.

CONCLUSION

Based on the data from this review, fitness testing results may be a reliable means of identifying individuals undergoing tactical training who are at a higher risk of sustaining an injury during their training. However, significant variation in fitness testing methods between organizations, roles, mission and size of each organization, differences in injury definition between publications and differing statistical approaches limits cross-study comparison and conclusiveness of findings. Nonetheless, all tactical organizations require both trainees and operational personnel to perform weight bearing activity with and without load over varying distances and speed.(48, 51) Because such activity is central and universal in many tactical settings, specific focus on weight bearing and loaded activity over distance should be considered and trainees should be appropriately acclimated. Our meta-analysis findings confirm this, with studies reporting categorical, fixed-distance timed run events indicating unequivocally that poor metabolic fitness carries an elevated risk of injury during initial tactical training. Strength and power measures correlated well with injury risk, but only four studies investigated a measure of strength, only two investigated a measure of power and only two of the strength tests were functional measures. Therefore, tactical organizations should promote metabolic fitness of trainees, acclimate trainees to weight bearing over distance, use fitness test results to identify personnel as at elevated risk of injury, and intervene appropriately. Further research should investigate implementation and effectiveness of field expedient measures of functional strength and power.

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