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Research Report

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The Army Combat Fitness Test (ACFT) and the Health of the Active Component

Understanding the Link Between the ACFT and Personnel Health and Injuries

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About This Report

This report documents research and analysis conducted as part of a project entitled *Understanding the Link Between the Army Combat Fitness Test and Personnel Health and Injuries*, sponsored by the Office of the Assistant Secretary of the Army for Manpower and Reserve Affairs. The purpose of the project was to provide in-depth analyses on Army Combat Fitness Test (ACFT) implementation and evaluate policy options that the U.S. Army could consider for optimizing physical readiness, general health, and well-being across the Army.

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Summary

The research reported here was completed in December 2023, followed by security review by the sponsor and the U.S. Army Office of the Chief of Public Affairs, with final sign-off in January 2025.

The Army Combat Fitness Test (ACFT) became the U.S. Army's physical fitness test of record in October 2022. The test consists of six events intended to measure muscular strength and endurance, power, speed, agility, aerobic endurance, balance, flexibility, coordination, and reaction time. One of the Army's stated goals for the test was to reduce injuries. More than half of soldiers experience a new injury in 2021, so success in reducing the risk of injury could have a significant impact on both medical costs and lost workdays. Because the ACFT has been administered for a relatively short period, there are limited data available to assess the relationship between the ACFT and soldier health and injuries. Nevertheless, this research effort used available data to gain initial insights into this relationship. This study was part of RAND's ongoing independent assessment of the ACFT, focusing specifically on injury risk.

To determine the empirical relationship between the ACFT and injuries, we reviewed the literature on the associations between fitness testing and injury rates, as well as existing surveillance systems and information. We also combined the Army's ACFT data on physical fitness performance with data from the Defense Health Agency on medical encounters and examined reported injury rates for the active component of the Army during periods when the Army Physical Fitness Test (APFT) was still in place, as well as during the rollout and full implementation of the ACFT. Most of our statistical analyses use tests collected after April 1, 2022, because the ACFTs recorded after this date are most representative of the state of current ACFT policies.

Key Findings

Looking across the varied analyses conducted, which included aggregate analysis of the Army as a whole and the injury and ACFT administration experiences of individual soldiers, we highlight eight key findings:

- **The timing of ACFT administration is strongly associated with injury risk.** Our data showed an increase in overuse injuries prior to the test date but no change in the rate of acute trauma injuries leading up to the test. This pattern could reflect changes in the frequency or intensity of training as soldiers prepare for the ACFT, but it also may reflect some set of soldiers proactively choosing to seek care for existing nagging injuries or seeking a permanent profile prior to taking the test.
- **Acute trauma and overuse injuries are a risk the day of the test.** We observed a brief spike in injuries on the date of the test and for several days into the 180-day window following the test date, which are likely to be injuries associated with the ACFT itself.

- **Risk of injury from the test appears to decline with experience.** The ACFT is new, and learning to train for and take new physical fitness assessments should be expected to carry some degree of injury risk that can attenuate over time. We observed a decline in injury incidence associated with a soldier gaining experience with the test.
- **The ACFT does not present a substantially greater injury risk than the APFT.** We compared injury rates six months before and after the ACFT with similar windows surrounding APFT tests and found that the pattern of observed injury for the ACFT was similar to that of the APFT.
- **Soldiers delay treatment when health care is harder to get.** We observed injury patterns that suggest that soldiers are likely delaying treatment (or that they face unavoidable delays from lack of health care access) for injuries when the test is run on Friday or Saturday relative to early in the week.
- **Injury risks for male and female soldiers differ by body region.** We observed some differences in location of injury by gender that warrant continued observation and may be targets for intervention. For both overuse and acute trauma injuries, women are significantly more likely to suffer lower-extremity injuries than their male counterparts, whereas men are correspondingly more likely to suffer upper-extremity injuries.
- **Overall ACFT performance is predictive of future injury risk.** Soldiers who failed the ACFT were about 20 percent more likely to suffer an injury in the 180-day window following the ACFT. In contrast, soldiers who scored higher on the ACFT overall had significantly lower risk of any injury even when compared with the group that received "narrowly passing" total scores on the ACFT (360–419). This pattern is driven mostly by cumulative microtrauma (or overuse) risk, although acute trauma risk is also associated with performance. Ultimately, better performance on the ACFT is associated with reduced risk of injury.
- **Most of the test components of the ACFT also show strong associations with future injury risk when considered individually.** Consistent with prior research, cardiorespiratory activities exhibited some of the strongest positive associations between performance and reduced injury risk. In general, the patterns found for the overall ACFT held (i.e., event failure was associated with a higher risk of injury, whereas better event performance was associated with lower risk of overuse injury). Some high-performance outcomes on events were linked to elevated risk. For example, among some soldiers, performance at the highest scoring tiers for 3 Repetition Maximum Deadlift, Sprint-Drag-Carry, and Standing Power Throw was associated with higher acute trauma risk.

To the extent that broader, more-holistic training is indeed motivated by the more-expansive physical requirements of the ACFT, the literature suggests that the ACFT could in the long term lead to an overall reduction in injury rates. Further monitoring of injuries, especially compiled with information on actual training programs, would bolster this conclusion.

Recommendations

Drawing on the findings of our analytical work and review of prior research literature, we offer the following recommendations, many of which focus on enhancing surveillance, data collection, and monitoring so that the Army has the information needed to make evidence-based decisions regarding future aspects of the ACFT:

- **Include additional relevant determinants of injury risk in surveillance and monitoring systems.** Demographic, occupational, and physical characteristics provide useful information about injury risk and injury associated with physical fitness training and assessments. Collecting this information in one place, in a time series for all relevant factors, will enable more fidelity in Army analysis of health and injury rates across installations and over time.
- **Enhance existing or establish new procedures to collect cause-of-injury data.** Information relating to the cause and setting for injuries is not consistently recorded but should at a minimum be collected alongside ACFT data at the time of the test, including instances in which soldiers fail the tests because of injury during one of the events. The location of the test, the weather, and other factors could also be collected during physical fitness assessments to help rigorously assess their influence on injury risk and performance. Similar data could also be collected on profiles issued as a result of injury.
- **Incorporate physical fitness assessments into injury surveillance.** ACFT scores have substantial predictive power in assessing an individual soldier's risk of injury. Including information on fitness performance (i.e., ACFT scores) in injury surveillance systems, and even in medical records, could be used as an early warning sign for risk. At a minimum, ACFT failures could be used to aid in targeting soldiers at risk potentially through resources from the broader Army fitness operating concept, Holistic Health and Fitness, where available.
- **Monitor ACFT performance throughout the performance range; do not focus only on those who do not pass.** Injury risk tends to be substantially higher for soldiers who fail any ACFT component. Yet acute trauma is also higher among male and female soldiers who are among the highest performers on some strength tests. Further assessments should be conducted to better understand this risk among high performers to ensure that standards are not set in ways that incentivize training and test-taking habits that induce excessive risk.
- **Continue to monitor injury risk and track trends.** Our analysis suggests that injury risk falls with experience taking the ACFT. This means that the overall injury risk associated with taking the ACFT during the periods we examined may continue to evolve. At the same time, as the stakes of the test increase for personnel actions, soldiers may be motivated to seek higher levels of performance in ways that increases risk. Continued monitoring of trends in injury risk and in the types of injuries incurred will help target areas in which potential intervention is needed.
- **Continue to systematically collect data on desired outcomes from investments such as Holistic Health and Fitness.** This program has not been in place long enough or implemented in a way for us to rigorously assess its impact on injuries with the data available during our study. But our literature review suggests that investments in this multidimensional initiative could have an impact on injury rates. The Army should seek service-wide evidence

and assess information on each of the dimensions of Holistic Health and Fitness to evaluate the success of this program as it is rolled out and use this information to make evidence-based decisions on implementation timing and future investments.

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Chapter 1

Introduction

In 2019, 55 percent of soldiers experienced a new injury or injury-related condition, nearly three-quarters of which were musculoskeletal in nature (U.S. Army, 2022). In the same year, the U.S. Army announced a new fitness test, the Army Combat Fitness Test (ACFT). Contemporaneous Army analyses reported modifications to the typical soldier's training activities, increases in self-reported injury risk, and changes in the composition of injury types observed as soldiers started training for and testing on the ACFT (U.S. Army Public Health Center [APHC], 2021). Two of the Army's stated goals for the ACFT at the time were to reduce injuries and to establish a *culture of fitness*. However, evidence regarding the relationship between the ACFT and soldier health and injuries remains limited because of the small window of time under which the ACFT has been administered, particularly in its current format and as the Army physical fitness test of record. This report examines the relationship between the ACFT and health—specifically, injuries—using these preliminary data.

Description of the ACFT

The ACFT is a six-event physical fitness assessment intended to measure muscular strength and endurance, power, speed, agility, aerobic endurance, balance, flexibility, coordination, and reaction time (Kimmons, 2018). At the time of the study, as an age- and gender-normed test, the ACFT was the physical fitness test of record to evaluate a soldier's physical fitness in the active component. Table 1.1 provides the Army's current description of ACFT events in sequence and the physical capabilities associated with each event, respectively.

Although the mission of the ACFT has evolved, the ACFT as implemented since April 1, 2022, has four stated goals (U.S. Army, undated):

- Improve soldier and unit readiness.
- Transform the Army's fitness culture.
- Reduce preventable injuries and attrition.
- Enhance mental toughness and stamina.

Table 1.1. Descriptions and Purposes of the Six ACFT Events

ACFT Event	Description	Purpose
3 Repetition Maximum Deadlift (MDL)	Deadlift the maximum weight possible three times	"The MDL assesses the Muscular Strength component of fitness by measuring a Soldier's lower body, grip and core muscular strength. It requires well-conditioned back and leg muscles and helps Soldiers to avoid hip, knee and lower back injuries. Flexibility and balance are secondary components of fitness assessed by the MDL."
Standing Power Throw (SPT)	Throw a 10-pound medicine ball backward and overhead for distance	"The SPT event assesses the Power component of fitness by measuring a Soldier's ability to generate quick, explosive movements with their upper and lower body. Secondary components of fitness assessed by the SPT include Balance, Coordination and Flexibility."
Hand Release Push-Up—Arm Extension (HRP)	Complete as many Hand-Release Push-ups as possible in two minutes	"The HRP assesses the Muscular Endurance component of fitness by measuring a Soldier's upper body endurance. The HRP is a strong driver for upper body and core strength training. Flexibility is a secondary component of fitness assessed by the HRP."
Sprint-Drag-Carry (SDC)	Conduct 5 x 50-meter shuttles for time—sprint, drag, laterals, kettlebell carry and sprint	"The SDC assesses the Muscular Endurance, Muscular Strength, Anaerobic Power and Anaerobic Endurance components of fitness by measuring a Soldier's ability to sustain moderate to high intensity muscular work over a short duration. Secondary components of fitness assessed by the SDC include Balance, Coordination, Agility, Flexibility and Reaction Time."
Plank (PLK)	Maintain a proper plank position for as long as possible	"The PLK assesses the Muscular Endurance component of fitness by measuring a Soldier's core strength and endurance. Balance is a secondary component of fitness assessed by the PLK."
Two-Mile Run (2MR)	Run two miles for time on a measured, generally flat outdoor course	"The 2MR assesses the Aerobic Endurance component of fitness. Higher aerobic endurance allows a Soldier to work for long periods of time and to recover more quickly when executing repetitive physical tasks."

SOURCE: The descriptions and purposes are compiled from U.S. Army, undated.

Implementation of the ACFT

We briefly describe some important dates in the ACFT rollout as they apply to our examination of ACFT's potential influence on the health—specifically, injuries sustained—of the Army. Key dates include the following:

- **October 29, 2019:** ACFT 1.0 initial plan was published. Six events with age- and gender-neutral physical fitness assessments were included: the MDL, SPT, HRP, SDC, leg tuck (LTK), and 2MR. The test standards aligned to military occupational specialty (MOS) tier. The initial plan was for the ACFT to be the physical fitness test of record by October 1, 2020 (Center for Initial Military Training, 2019).

- **June 12, 2020:** ACFT 2.0 guidance was published as a memorandum. The PLK was introduced as a pass-fail alternative to the LTK. Individual MOS standards were eliminated and replaced with the gold standard of 60 points per event (Secretary of the Army, 2020).
- **October 1, 2020:** The ACFT was launched as a diagnostic test but was not used for administrative actions. The most recent Army Physical Fitness Test (APFT) performance continued to be used for adverse (separations) or professional (promotions) administrative purposes through March 31, 2022 (Secretary of the Army, 2020).
- **April 1, 2021:** ACFT 3.0 guidance was implemented. A PLK scoring table was added as a full alternative to the LTK. Minimum age- and gender-neutral standards were retained. Adverse actions continued to be paused (Center for Initial Military Training, 2021).
- **April 1, 2022:** The ACFT became effective (Secretary of the Army, 2022). Age- and gender-normed scoring scales were introduced using evidence from more than two years of diagnostic ACFTs. The LTK was fully replaced by the PLK event. Tests were treated as diagnostic, with an option for these tests to be recharacterized as for-record tests at soldiers' request. Recharacterized tests would begin to count for record starting in October 2022 regardless of when they were taken during the diagnostic window.
- **October 2022:** Regular Army, Active Guard Reserve, and soldiers on active duty orders started taking the ACFT for record on October 1, 2022. One test is required every six months. The ACFT became usable for administrative actions, including retention and evaluation. As a result, the ACFT begins to have career implications and fully transitioned to a high-stakes assessment in which not passing has consequences.
- **April 2023:** Army Reserve and Army National Guard soldiers started taking the ACFT for record. Passing scores begin to be used for personnel actions. All Regular Army and Active Guard Reserve soldiers must have a for-record ACFT no later than April 1, 2023.
- **April 2024:** Reserve component soldiers must have a for-record ACFT no later than April 1, 2024 (U.S. Army, undated).

Interested readers may find more-detailed timelines for and discussion of the first two years of the ACFT rollout in Hicks and Robson (forthcoming).[1]

ACFT and Injuries

Prior RAND evaluations of the ACFT have focused predominantly on soldier pass rates (Hardison et al., 2022) and on closing remaining information gaps (Hicks and Robson, forthcoming). Academic research has linked various measures of physical fitness to injury risk.[2] However, as Hardison et al. (2022) noted, additional evidence would be helpful to establish the test's validity and its value as a predictor of fitness culture, readiness, and injuries. Thus, the primary goal of the current study is to provide evidence to better understand the relationship between the ACFT and injuries.

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[1] Additional detail may be found on the Army ACFT website itself. See U.S. Army, undated.

[2] See, for example, de la Motte et al., 2017; de la Motte et al., 2019; Lisman et al., 2017; also see Appendix E.

Relatively little guidance, policy, or research addresses the mechanisms through which the ACFT is intended to transform the Army's fitness culture or enhance mental toughness and stamina. There are theoretical reasons to think that a broader physical fitness assessment than the APFT—with requirements to train for a wider range of physical capabilities—would lead to a healthier, more lethal force.[3] In contrast to typical preparation for the APFT, preparation for the ACFT requires the adoption of different training activities that enhance not just cardiorespiratory fitness but also fitness components not directly assessed by the APFT, such as muscular strength, power, and agility.[4] Some ACFT guidance suggests that aspects will enhance mental toughness (for example, Army Techniques Publication 7-22.01 states that requiring the attempt of all events, even if an early event in the testing sequence has been failed, will enhance "tenacity" [2022, p. 2-11]). These alternative goals of the ACFT, such as developing a culture of fitness, might suggest other justifications for specific test components and administration, including the greater emphasis on strength training associated with the shift in exercises from the APFT to the ACFT. However, as a set of established fitness activities, the theoretical impact of the ACFT on injury risk is clearer.

Consideration of how the ACFT relates to injuries takes a number of forms. The possibility that the test itself could cause injury should not be discounted. Given the motivation incurred during high-stakes testing, it is entirely possible that soldiers may push themselves to the limit to achieve the highest score possible on each of the sequence of events. The Army provided an assessment of the general risks associated with the new test in 2020. Table 1.2 adapts the Army's table, describing the potential risks for given body regions and types of potential injuries (Hauschild, 2020, Table 1). This table was developed prior to the replacement of the LTK with the PLK and hence does not provide an assessment of relevant body regions and injury types associated with the PLK. In general, the literature speaks to the utility of the PLK as an exercise for core stability. But like any exercise event for which it is possible to train, it is possible to experience injuries because of improper form with the PLK (see, e.g., Childs et al., 2010; McGill, 2010).[5] Muscle groups or body regions that may be strained during improper execution of the PLK are the neck, shoulders, and back.

The ACFT may contribute to injury via its influence on how soldiers train in preparation for the test, especially to the extent that soldiers do not train with proper form. As noted by Hardison et al. (2022), during the ACFT diagnostic period, initial evidence was accumulating that a greater emphasis was being placed on resistance training and a lower emphasis on cardiorespiratory training (in particular, running) during Army training in preparation for testing. Engaging in a new training regimen may temporarily increase risk of injury (Grier et al., 2013).

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[3] The APFT consisted of two minutes of push-ups scored on repetitions, two minutes of sit-ups scored on repetitions, and a two-mile run scored on time. Each event was scored on a 100-point, age- and gender-normed scale, with 60 points required in each event to pass.

[4] Cardiorespiratory fitness is the ability of the heart and lungs to deliver oxygen to (exercising) cells. Its most common measurement is VO_2 max. A more commonly encountered term, *cardiovascular fitness*, is a subset of cardiorespiratory fitness and pertains to the capacity of the heart, arteries, and veins to deliver blood to the body. In this report, we use the broader term, *cardiorespiratory*, because of its greater utility in exercise physiology and consistency with Field Manual (FM) 7-22 (2020), *Holistic Health and Fitness*.

[5] Although the term *core stability* appears to be used broadly to mean many things, one functional definition as noted in Huxel Bliven and Anderson (2013, p. 514) suggests "the core as the foundation of the kinetic chain responsible for facilitating the transfer of torque and momentum between the lower and upper extremities for gross motor tasks of daily living, exercise, and sport."

Table 1.2. Anticipated Injury Risks Associated with ACFT Events

ACFT Event	Injury Risk to Body Regions	Injury Risk Types
MDL	Knees, lower back	• Musculoskeletal (MSK) and nerve tissues • Acute sprains, strains, ruptures • Cumulative (also referred to as *overuse*) tendons, ligaments, spine
SPT	Back and neck (spine), shoulders	• MSK, nerve • Acute strains, sprains
HRP	Shoulder, elbow, back, neck	• Acute MSK strains, ruptures • Cumulative tendons, ligaments
SDC	Knees, shoulders, elbows, back	• Acute MSK strains, tears (e.g., ligament tears) • Cumulative (e.g., tendonitis)
2MR	Knees, leg, feet, hip/pelvis	• Acute MSK (e.g., fractures, sprains from • falling, or muscle, tendon, or ligament tears) • Cumulative tendons, ligaments • Foot blisters

SOURCE: Text adapted from Hauschild, 2020, Table 1.

Finally, the ACFT may influence injuries in the desired sense: To the extent that a broader range of fitness activities is undertaken to continue to pass the test, broader physical fitness and capacity across the force may decrease injuries incurred through this new culture of fitness. Although the weight of evidence supporting the link between fitness and health or injury is strongest for cardiorespiratory health, other types of physical capacities are also linked with injury experience, such that greater levels of fitness are typically related to reduced injury risk (see reviews in de la Motte et al., 2017; de la Motte et al., 2019; Lisman et al., 2017; see also Appendix E).

The initial goals of the ACFT included a reduction in injuries and the creation of what the Army terms *a culture of fitness* with occupational-specific tiering. During the rollout period, the focus of the ACFT shifted away from occupational demands, and now the assessment places more emphasis on force-wide general fitness levels, with age and gender norming. The change to age- and gender-normed scoring recasts the ACFT to what has been termed a *tier 1* fitness assessment (Robson et al., 2021). Tier 1 tests are tests that target a service as a whole with the aim of promoting general fitness and reducing health risks associated with a general lack of fitness. The second type of tests, tier 2 tests, are those that are designed to facilitate the accomplishment of physically demanding job-related tasks (such as for specific occupations) and assess readiness to perform those demanding physical tasks to standard. The ACFT in isolation will not meet all the goals articulated for its use. However, the ACFT is only the testing component of the broader Army fitness operating concept. The current system of fitness is Holistic Health and Fitness (H2F) (Field Manual 7-22, 2020).

Evolution of Army Fitness Doctrine

The H2F system is the third iteration of the Army fitness system since 2010. It replaced the Army Physical Readiness Training (APRT) in 2020, which itself replaced the Army Physical Fitness Training system in 2010. All three systems share similar stated goals: to ensure that soldiers are ready for combat and to design fitness programs that are tied to fitness assessments rather than battlefield requirements.

Prior to 2010, FM 21-20 (1998), *Physical Fitness Training*, emphasized the importance of "train[ing] as you fight," that "physical training programs must do more for our soldiers than just get them ready for the semiannual Army Physical Fitness Test (APFT)," and that an effective fitness regime would "reduce the number of soldiers on profile and sick call." However, by 2010, it was clear to Army leaders at the U.S. Army Physical Fitness School that these goals were not being met (Lewis, 2010). Most actual fitness training instead focused on muscular endurance and cardiorespiratory conditioning, with muscular strength and mobility taking a much lower priority. This focus reflected the testing priorities of the three-event APFT, which tested only push-ups, sit-ups, and the two-mile run. In addition, the training guidance of FM 21-20 lacked specificity, with contemporaneous complaints that the system was conceptually broad, but, because most leaders lacked the training to properly implement it at the unit level, it generally devolved into APFT-focused circuits or cardio events, such as runs or road marches (Lewis, 2010).

FM 21-20 was followed first by a training circular in 2010 and then by a fully updated FM, 7-22, *Army Physical Readiness Training*, in 2012. The APRT system introduced modular drills with increased focus on strength and mobility. These drills greatly simplified fitness training design for unit leaders, who could now execute a fitness regimen directly from the FM, rather than taking fitness concepts and trying to design a fitness plan on their own. However, Army fitness experts continued to recognize the limitations of the three-event APFT as the physical test of record (Lewis, 2010). This led to initial studies on new fitness test components that eventually culminated in the six-event ACFT.

The H2F system builds on the Army Physical Readiness Training system and replaced it as the operating concept in FM 7-22 in 2020. H2F combined multiple strands of Army fitness design that evolved over the 2010–2020 period, such as the *performance triad* concept of physical activity, sleep, and nutrition that the Army initiated in 2013 (Army Techniques Publication 6.22-5, 2016). As stated in the 2020 operating concept, "The Holistic Health and Fitness (H2F) System is the Army's primary investment in Soldier readiness and lethality, optimal physical and non-physical performance, reduced injury rates, improved rehabilitation after injury, and increased overall effectiveness of the Total Army" (Center for Initial Military Training, 2020, p. 2).

As part of this effort, FM 7-22 has been rewritten to provide a strategic underpinning to the H2F system, with an emphasis on five domains of health, both physical and nonphysical: physical readiness, mental readiness, spiritual readiness, nutritional readiness, and sleep readiness. Moreover, there is an emphasis on individualized training progression and needs that differs from the more traditional, mass-produced Army approach to physical fitness. Building off Army Physical Readiness Training, FM 7-22 continues to provide templates for various physical training progressions, with a note that these should be adapted to individual and unit needs (earlier editions offered training template schedules with stated emphasis on the principles of training as you will fight, training to standard, and training to develop agile leaders and organizations). Work examining injury rates in the Army has noted that gradual increase in training volume along with a plan that entails both weight training for muscular strength and running or other sessions to enhance cardiorespiratory fitness (i.e., a holistic approach) can bear fruit in terms of injury reduction (e.g., Grier et al., 2013; Molloy, Pendergrass, Lee, Hauret, et al., 2020).

The H2F system provides resources to achieve these ends in the form of trained personnel of varying expertise to act as resources (including not only strength and conditioning specialists but also dieticians and physical therapists, among others; Center for Initial Military Training, 2020). The system also provides for the provision of equipment to facilitate the needed work. Rollout is phased over multiple years, since the acquisition and training of requisite personnel takes time, as does the acquisition and distribution of equipment (Bigelman, 2021).

Parks et al. (2022) conducted a small study that compared directed, expert-led fitness training regimens with nondirected, traditional ones. Using 12-week Officer Candidate School classes as comparison groups, the researchers studied two types of fitness programs. The first was a traditional 25-session training-to-the-test physical fitness program that focused on running (12 sessions) and circuit drills (13 sessions) that replicated ACFT activities. This training was designed and led by the officer candidates themselves, none of whom was an expert in exercise science. The second type involved a more tailored fitness program that controlled running volume and incorporated resistance training and recovery while focusing less on ACFT events. Training for this second group was designed and led by certified fitness experts from the Tactical Athlete Performance Center on post at Fort Moore, Georgia. For the majority of ACFT events, the traditional, nonexpert group did better on ACFT events, scoring 15 points higher, on average, than the expert-led group. However, the study lasted only 12 weeks, which might not capture the long-term benefits of expert-informed foundational work. The study also did not compare injury rates, which is the focus of this report. Thus, the benefits of directed H2F fitness instruction remain a gap to be addressed by future research.

Objectives and Approach

This report presents findings from an ongoing independent assessment at RAND of the ACFT, focusing on providing quantitative evidence regarding the relationship between physical fitness and health as evidenced by injuries. Specifically, we seek to determine whether ACFT performance is related to a reduced risk of injuries, as might be expected based on the literature. We also seek to examine risk of injuries around the ACFT administration itself to illuminate whether the ACFT itself poses a risk for injury.

To produce this analysis, we combined data on physical fitness performance from the Army with information from the Defense Health Agency (DHA) documenting diagnoses for injuries among Regular Army soldiers.[6] Together, these records provide a picture of all care that active soldiers received in both inpatient and outpatient settings and at military treatment facilities (MTFs), in theaters, and outside MTFs. These files present observations of medical encounters with such elements as patient information, date of service, and information about the diagnoses associated with

[6] Unless otherwise noted, data were provided to RAND by the Army and DHA.

that patient visit. Information on diagnoses is recorded using International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) diagnosis codes (National Center for Health Statistics, undated).[7]

We used the primary diagnosis codes to create a variety of indicators that flagged receipt of a diagnosis for mechanical energy injuries. In consultation with clinical experts and the literature, we applied the APHC injury taxonomy to classify diagnosis codes, which did not include counting diagnosis codes for follow-up care—subsequent or sequela encounters—as new injuries (see, e.g., Hauschild et al., 2021). This taxonomy defines an injury as "bodily damage caused by the instantaneous or gradual transfer of mechanical, chemical, electrical, radiological energy to the body or the restricted transfer of an essential element such as oxygen" (APHC, 2022, p. 2). Mechanical injuries are those ascribed to a mechanical cause. These include musculoskeletal injuries (MSKIs): acute trauma or cumulative microtrauma (overuse). MSKIs are those that affect the MSK system (bones, muscles, tendons, joints, ligaments, fascia, bursa). *Non*-MSK mechanical injuries affect other internal systems (digestive, circulatory, nervous, respiratory, integumentary) and examples include blisters, punctures, and internal organ damage. The data provided to RAND by the Army for physical fitness measures include test records spanning October 1, 2020, through March 31, 2023, whereas the DHA injury data cover the period from 2016 to March 2023, when ICD-10-CM codes were in use consistently.[8]

Organization of This Report

This report contains analyses of the relationship between the ACFT and soldier injuries. In Chapter 2, we present aggregate evidence regarding the general health of the force and the existing burden of health expenditures. We also present trends and statistics to contextualize the ACFT, especially within the context of the H2F system within the Army. The ACFT and H2F must be understood in the context of a U.S. population evidencing significant negative trends in physical and behavioral health. The Army is a reflection of the U.S. population, and these shifts impose significant challenges for recruitment and retention eligibility. In Chapter 3, we present the results of analyses of the relationship between ACFT and injury, focusing on the timing of these injuries and profiles of physical, demographic, and occupational factors associated with injury risk in the active component population. Chapter 4 focuses on the relationship between the ACFT and future injury risk. The final chapter provides a summary and recommendations.

The report contains several supporting appendixes. Appendixes A and B describe data and detail the approach to the empirical analysis, respectively. Appendix C contains information on injury classification, and Appendix D contains installation injury rates. In Appendix E, we present the results of a survey of existing research exploring the relationship between physical fitness assessment, health, and injury risk.

[7] The ICD-10-CM coding system is used to categorize both procedures and diagnoses; our analyses focus on the diagnosis codes and more specifically the primary diagnosis code.

[8] Data prior to October 1, 2020, reflect a period in which the ACFT was a field trial rather than a force-wide diagnostic test. See Hardison et al. (2022) for additional details.

Chapter 2

Injuries, Health Indicators, and Health Care Expenditures

In this chapter, we present aggregate evidence regarding injuries occurring in the force over time, the financial burden of injuries, and other indicators of health and well-being relevant to the ACFT and the U.S. Army. These trends and statistics serve to contextualize how the ACFT and related health and fitness investments within the Army, such as H2F, must be understood, especially in the context of a U.S. population emerging from the COVID-19 pandemic with significant recent changes to physical and mental health. We focus our attention on descriptive evidence regarding the frequency and composition of injuries among Army personnel before and after the implementation of the ACFT and H2F, and we discuss aggregate factors and policy developments that may have affected these patterns.

Injuries have a sizable impact on the aggregate readiness of Army personnel. Prior studies have estimated that, at any given time, approximately 10 percent of soldiers cannot be deployed for medical and administrative reasons (Taylor-Clark et al., 2023). According to the *2022 Health of the Force* report, 52 percent of soldiers sustained an injury over the course of 2021. There were notable age and gender differences in injury incidence. Injury is associated with older age: 69 percent of active duty soldiers over age 45 reported an injury, compared with only 49 percent of soldiers under age 25. Looking only at gender, differences were smaller than those for age, with 61 percent of active duty females reporting an injury, compared with only 51 percent of males (U.S. Army, 2022).

More than three-quarters of observed injuries in the Army are overuse injuries. Although the Army has multiple active interventions to reduce injuries nested within H2F, overuse and traumatic injury rates in the active component are significantly higher in the Army than those in in Navy, Marine Corps, and Air Force. There are some limitations to comparisons outside the Army, including demographic differences across U.S. Department of Defense components, yet the overall picture presented suggests that the Army has potentially the most to gain from reducing preventable injuries (U.S. Army, 2021).[9]

In addition to readiness concerns, injuries create a substantial financial burden for the Army. In 2018, injuries accounted for direct care costs in excess of $430 million, making up 42 percent of all outpatient visits and 15.2 percent of hospitalizations (Taylor-Clark et al., 2023). Hospitalization days and limited duty days are one way to estimate of the burden of injuries. A 2022 study using calendar year 2018 injury data estimated the total cost of MSKI—injuries to bones, muscle tissue, or

[9] Acute injury rates in the Army were 291 per 1,000 active component service members in 2021. Respective figures for the Navy, Air Force, and Marine Corps are 174, 212, and 257 per 1,000. Cumulative microtrauma injuries in the Army were 1,069 per 1,000 active component service members in 2021 in comparison with Navy, Air Force, and Marine Corps rates of 552, 764, and 812 per 1,000, respectively (U.S. Army, 2021).

ligaments—at more than $4.2 billion, after including both direct treatment costs and indirect costs, such as lost duty days (APHC, 2022). Profiles because of MSKIs resulted in 8.8 million limited duty days in 2021 in a force of 482,000 active duty soldiers—the equivalent of losing the services of 24,100 active duty personnel for the year (U.S. Army, 2022). That equates to more than 5 percent of total Army manpower, or roughly two divisions of soldiers.

Estimated Injury Costs by Type and General Body Region

The Army's Defense Centers for Public Health—Aberdeen provides data on costs by injury type and injury location. These data are reported here to contextualize the importance of studying injury incidence *and* injury composition jointly as they relate to the ACFT. These costs reflect the direct treatment costs and indirect costs—such as lost duty days because of full or limited profiles—that an average injury imposes on the total active duty force. Table 2.1 lists the average costs for acute and cumulative microtrauma (overuse) injuries. Table 2.2 breaks down average total and medical encounter costs by general body region.

Table 2.1. Estimated Costs per Injury and Encounter for Acute and Overuse Mechanical Energy Injuries

Type of Injury	Cost per Injury	Cost per Encounter
All non-MSK	$3,770	$2,120
Acute, non-MSK	$3,856	$2,599
Cumulative, non-MSK	$3,639	$1,629
All MSK	$6,338	$1,798
Acute, MSK	$7,866	$4,245
Cumulative, MSK	$6,108	$1,617

SOURCE: Features data from Forrest et al., 2022.
NOTE: For definitions of MSKI and non-MSKI, refer to the discussion of Army injury taxonomy in Chapter 1.

MSKIs represent the majority of total incidence of injury in the active duty force. They are also more expensive to treat. The average MSKI costs two-thirds more to treat than an average non-MSKI. Changes in injury incidence, type, or location that are driven by the ACFT may have a sizable financial and readiness impact on the Army force structure. Molloy, Pendergrass, Lee, Chervak, et al. (2020) described the impact that MSKIs have on readiness, citing effects on duty days lost and overseas curtailments because of MSKIs, as well as cost estimates that go beyond those for direct care. The authors noted that the cost of first-year attrition because of MSKIs over the period 2011–2016 could be as much as $88 million. These authors further discussed the long-term impact of MSKIs in terms of disability discharges and noted that it was potentially considerable given that reports that

MSKIs factor into the majority of disability discharges. However, the authors were not able to provide a cost estimate.[10]

Table 2.2. Estimated Cost per Injury and Encounter for Acute and Overuse Injuries by General Body Region

Body Region	Cost per Injury	Cost per Encounter
Overall average	$5,962	$1,824
Head and neck	$3,385	$2,150
Spine and back	$6,558	$1,700
Torso	$5,613	$3,614
Upper extremity	$6,744	$1,839
Lower extremity	$5,867	$1,856
Other	$3,252	$1,758

SOURCE: Features data from Forrest et al., 2022.

Administrative records contain some direct information on the underlying cause of injuries sustained (i.e., beyond those assigned by the taxonomy's categorization of diagnosis codes to mechanical, chemical, electrical, and radiological energy) and are reported in the *2022 Health of the Force*: 27 percent of these injuries occurred during running, 13 percent occurred during MOS-related work tasks, 12 percent were gradual-onset injuries, 9 percent were due to falls (including during sports), and 8 percent were due to weight training (U.S. Army, 2022). Unfortunately, this information is collected for only a small sample of injuries sustained, and it is unclear how representative this sample is of overall injury causes. However, in an average year, the vast majority of injuries are not tagged with a relevant cause code during processing. In 2021, 90 percent of injuries were not tagged (U.S. Army, 2022). In some years, the untagged rate exceeded 94 percent. Data entry practices will need to improve to enable statistically robust findings on injury causes over time or in relation to the ACFT and the H2F operating concept.

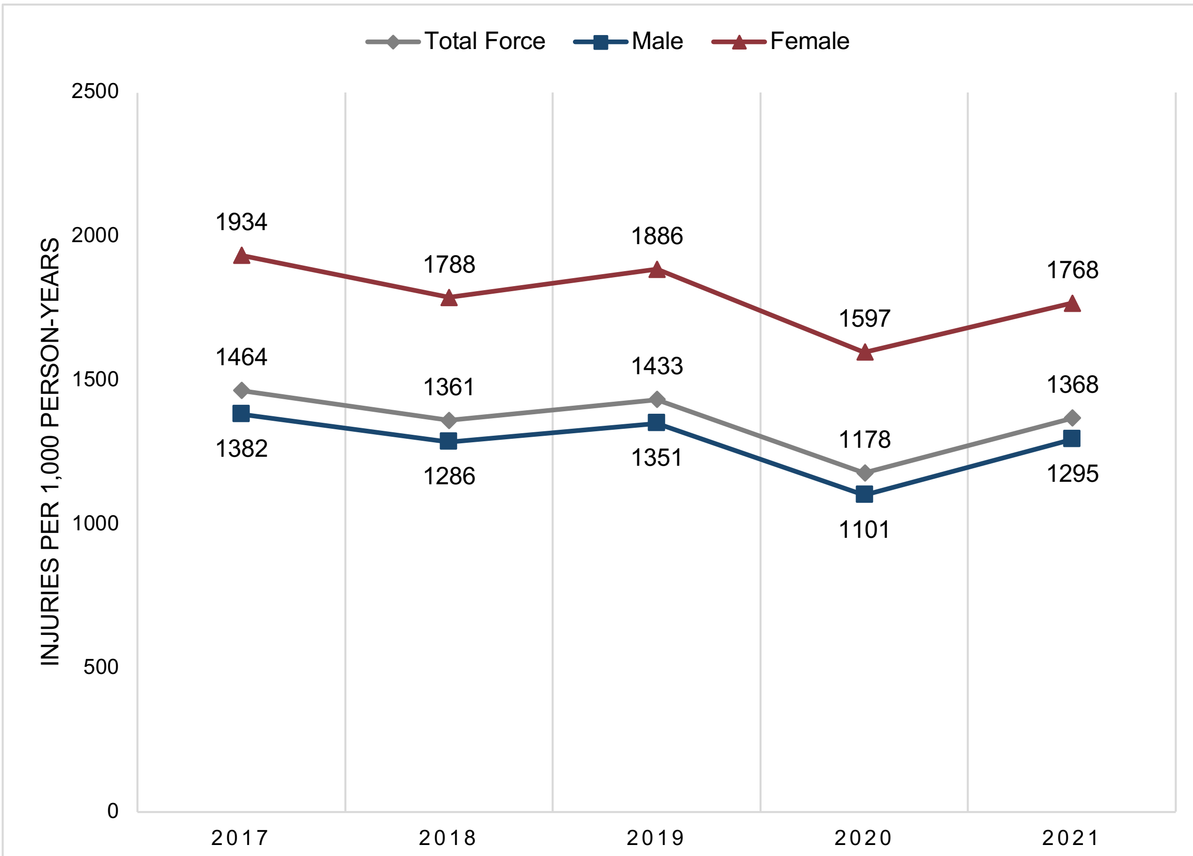
Injury Incidence Rates Since 2017

The rate of injury incidence for active component soldiers—i.e., the number of injuries per person-year—has declined over the past five years, as can be seen in Figure 2.1, which depicts injury incidence from 2017 to 2021 for males, females, and the total force. Note that during this period, female soldiers reported injuries at a rate 40 percent higher than male soldiers. This parallels the

[10] Although the discussion in Molloy, Pendergrass, Lee, Hauret, et al. (2020) focused primarily on years prior to 2017, the time frame did include informative perspectives from the conflicts in Iraq and Afghanistan, noting that nonbattle injuries accounted for 30 percent of medical evaluations from theater. The authors go on to summarize efforts to reduce injury incidence, including standardization of physical therapy and the advent of the H2F system.

exercise science literature on injury risk, which has found similar higher injury incidence among females (see Appendix E).

Figure 2.1. Active Component Injuries over Time



SOURCE: Features data from the 2018–2022 *Health of the Force* reports, available at Defense Centers for Public Health—Aberdeen, undated.

Although the downward trend in injuries among Army personnel between 2017 and 2021 is a positive sign, it may be premature to fully attribute aggregated trends to the implementation of the ACFT. Time-series population-level estimates that attempt to assess the impact of moving from the APFT to the ACFT on the overall rate of injuries in the Army entail some careful caveats. First, the rollout of the ACFT coincides with the COVID-19 pandemic, which affected both health and behavior through effects on morbidity, physical fitness routines, and selection into and out of the Army. In addition, the general health and fitness of the U.S. population, and that of the armed forces, has been changing over time. Finally, although the APFT has been used since the 1980s, medical codes used to classify the rate of injuries changed in 2016 and affected the frequency of injury diagnoses (Molloy, Pendergrass, Lee, Chervak et al., 2020). Therefore, comparisons over longer time spans necessitate consideration of that issue.

Injury Incidence Varies Across Army Installations

Injury incidence varies sizably across Army installations and across years for the same installation. As an example, Fort Riley, Kansas, which houses the 1st Infantry Division and 15,127 soldiers, had the lowest reported injury rate (849 injuries per 1,000 soldiers) in 2022 (data from the Health of the Force online; see DHA—Public Health, 2022).[11] The highest reported injury rate occurred at Fort Jackson, South Carolina (2,084 injuries per 1,000), with an active duty population of 8,100 soldiers. Many factors affect injury risk, ranging from demographics to unit type. The 1st Infantry Division is task organized as a combined arms division, and 85 percent of Fort Riley's population is below 35 years old. Fort Jackson has similar demographics but hosts a large population in basic combat training. Fort Belvoir, Virginia, has no combat arms units, but its active duty population (3,000) is much older—with only 47 percent below age 35—and younger soldiers face significantly lower injury risk profiles irrespective of military occupation.

Appendix D presents analysis of injury risk for large Army installations, contrasting injury risk that has been adjusted for demographics and physical characteristics of soldiers with published estimates of injury rates within the APHC dashboard. Our analysis suggests that, after accounting for many of the determinants of injury risk, some installations regularly rank better or worse when compared with their peers. This is important because gauging the success of installations in reducing preventable injury and the value of health interventions could be done using conditional injury risks—i.e., a health intervention targeting a population of 18-year-old soldiers in basic training may be expected to have a different impact than one targeting a base with older soldiers or with a larger percentage of officers relative to enlisted.

The Composition of Injuries over Time

In classifying injuries in our data, we followed the APHC injury taxonomy (see, e.g., Hauschild et al., 2021) to further segment these injuries into acute and cumulative MSKI and non-MSKI categories. (See Appendix C for further details on application of the APHC injury taxonomy and how we track injuries.) As would be expected based on prior APHC data using similar definitional rules on injuries and according to the most recent report available, MSKIs represented 81 percent of all injuries suffered by active duty soldiers and 84 percent of mechanical energy injuries in 2021 (Mahlmann, Schuh-Renner, and Canham-Chervak, 2023).

Although it is difficult to draw firm conclusions regarding the level of injuries sustained over time because of external factors, such as COVID-19 and changing population health, a less challenging comparison involves assessing the share of injuries across different body regions at different points in time. The composition of incidence of mechanical injuries sustained in a year prior to the ACFT, such as 2018, differs from those sustained in a year after the test had rolled out, such as 2021. Using consistent injury definitions provides indicative evidence that the pattern of injuries experienced by Army personnel has changed, as illustrated in Figure 2.2.

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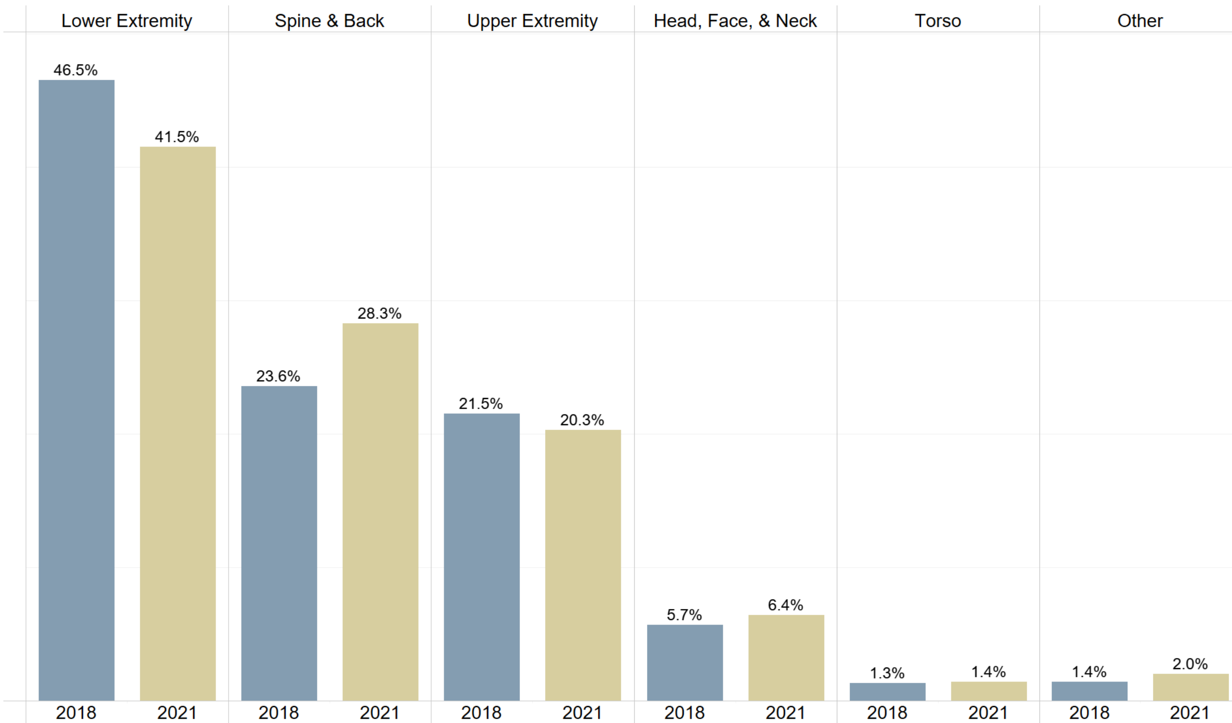
[11] These numbers are calculated from medical encounters recorded at base facilities.

Figure 2.2. The Composition of Injuries by General Body Region Under the APHC Injury Taxonomy



SOURCES: Features data from U.S. Army Public Health Center, 2018, 2021.
NOTE: Data include mechanical injuries only.

Comparing injury rates by body region between these two points in time (2018 and 2021) shows that injuries to lower extremities have decreased as a proportion of total injuries, while injuries to the spine and back have increased. These changes may be due to changes in the H2F physical fitness regimen but require further study because of the limited amount of units utilizing H2F techniques. An increased emphasis on strength training and a reduced emphasis on running will likely result in a different preponderance of injury types. In addition to training differences under H2F, the ACFT contains three exercises that engage upper posterior chain muscles: the MDL, SPT, and SDC. The previous test of record (the APFT) did not evaluate muscles in the upper posterior chain, although many soldiers reported back injuries because of the sit-up event (Evans et al., 2005). Injuries in other body regions have not changed substantively.

The pattern of injuries by body region should be monitored to ensure that medical staff are aware of the distributional change in injury risk and to ensure that mitigation resources are employed to target these risks. Changes to the pattern of injuries over time can affect costs as well. Figure 2.2 suggests that spine and back injuries are proportionally more prevalent in the years since the ACFT, whereas lower-extremity injuries were more prevalent in years during which the APFT was the test of record. Spine and back injuries are on average slightly more costly than those for lower extremities, as indicated in Table 2.2.

Some of these differences in injury incidence could also inform Army decisionmaking by, for example, helping to identify targeted adjustments to the fitness regimen to minimize risk for certain types of injuries. However, it is challenging to extrapolate injury frequencies and costs without a longer track record of ACFT performance.[12] If injury rates decline with training and activity experience, then the initial increase in the preponderance of spine and back injuries could be transitory as soldiers adjust to new exercises and fitness test events. For example, the increase in spine and back injuries occurred in tandem with renewed unit-level physical activity and physical fitness testing after the COVID-19 pandemic, and there are anecdotal reports of divergent fitness responses to the pandemic by soldiers, with some training more and some training less (Aker, 2021). Overall, we cannot disentangle the causality of renewed physical activity from the adoption of the ACFT. Also, injury rates may fall over time as soldiers become accustomed to new activities and familiarize themselves with, for example, the biomechanics of the deadlift exercise.

Trends in Body Mass Index and Changes in the Body Composition Program

The Army currently collects data on height and weight, used to compute body mass index (BMI),[13] and monitors body fat. Figure 2.3 presents the share of soldiers testing in a given month by BMI categorization. As can be seen from the figure, the share of the force classified as obese or overweight has risen, potentially a cause for concern. As our literature review indicated, individuals with high BMI are, on average, at greater risk of injury than those with normal BMI scores (see Appendix E).

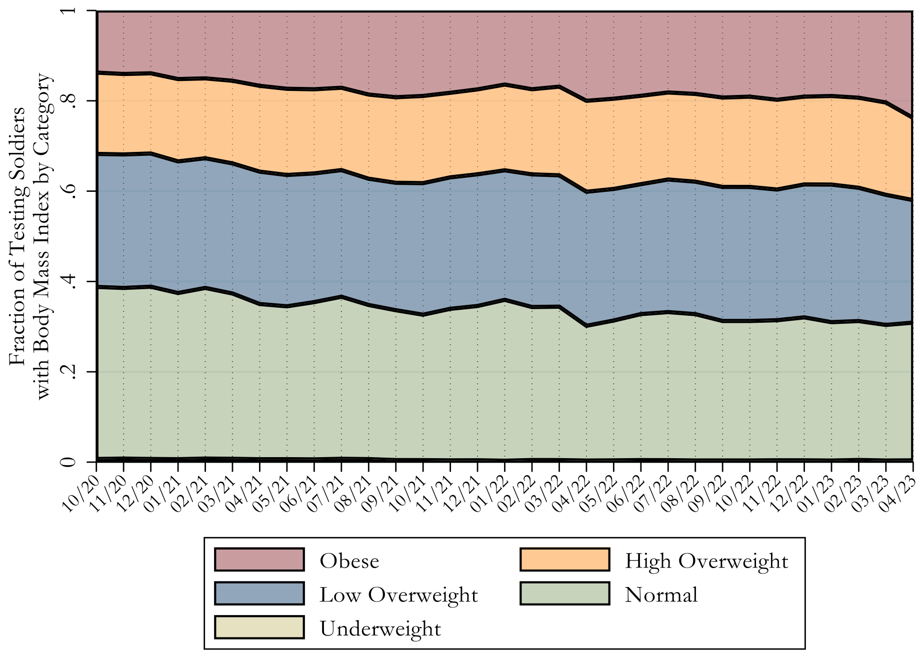
We calculated BMI trends using ACFT records, our primary data source. As a result, these measures of BMI do not depict the exact body mass composition of the force in any given month but instead the composition of soldiers choosing to test in that month. Thus, these data overcount soldiers who take the test more frequently, suggesting that the value observed in any given month should be viewed with some degree of uncertainty but should still provide a picture of trends in BMI over time.

It is noteworthy that BMI among Army personnel (2020–2023) mirrors a similar trend in the general population, as seen in Figure 2.4. As a result, increasing rates of overweight and obese BMIs is not unique to the Army and is a trend observed across the services (Meadows et al., 2021). These ongoing trends pose a concern about the overall health of the force, as well as about the population of eligible entrants to the services decreasing apace and recruiting challenges accruing.

[12] From 2017 to 2022, overall injury incidence decreased in terms of injury incidence per person-year across all categories, as seen in Figure 2.1. The increase in the proportion of spine and back injury incidence cannot alone demonstrate that spine and back injury incidence increased. Combining frequency data, we see that actual spine and back injury incidence has also fallen, just by less (2.1 percent) than overall injury incidence rates have fallen (4.0 percent). This cross-period comparison of injury incidence, while useful to policymakers, reflects statistical changes in both the numerator and denominator across periods.

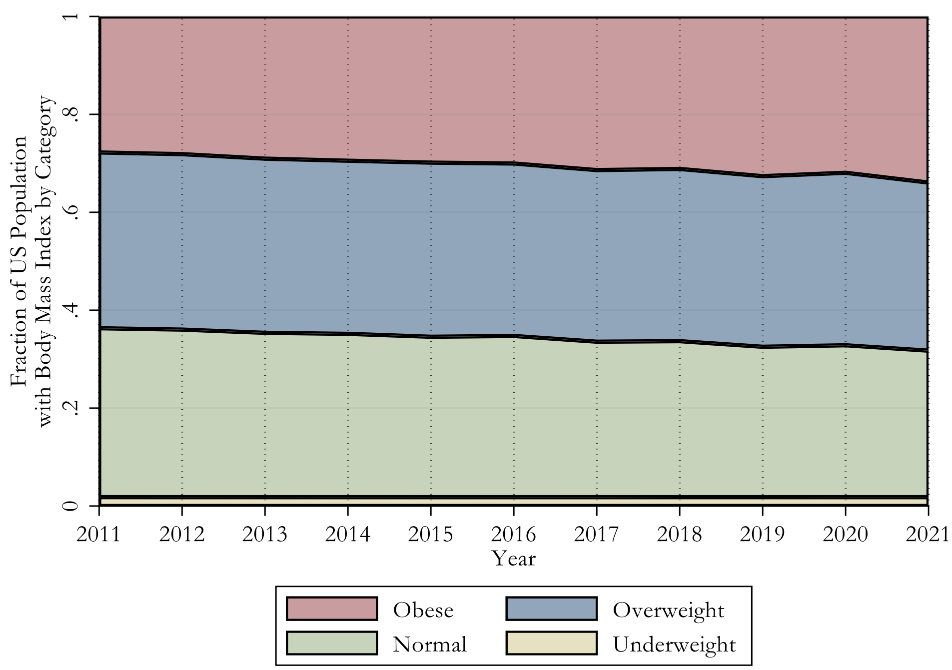
[13] BMI is unable to distinguish between fat and muscle content, and highly muscular individuals will also have a high BMI.

Figure 2.3. Trends in Body Mass Index Among Soldiers Taking the ACFT



SOURCE: Authors' calculations using ACFT dates and injury records provided to RAND by the Army.

Figure 2.4. Trends in Body Mass Index Across the U.S. Population



SOURCE: Authors' calculations using Centers for Disease Control and Prevention (CDC) Behavioral Risk Factor Surveillance System data (CDC, 2024).

The Department of the Army made two major changes to the Army Body Composition Program (ABCP) in 2023, at the time this report was being written: (1) an exemption to the ABCP based on high ACFT scores and (2) a shift from multisite to single-site circumference-based tape methods. The ABCP is designed to ensure optimal body fat standards within all three Army components through the policies and procedures described in Army Regulation 600-9 (2019). Army Directive 2023-08, published in March 2023, established a fitness score exemption for the ABCP (Secretary of the Army, 2023a). This exemption is designed to ensure that highly fit soldiers are not adversely affected by body composition standards and to motivate soldiers to aim for high ACFT scores to secure an ABCP exemption. Soldiers who score at least 540 out of 600 points overall and above 80 points (out of 100) in all six ACFT subcomponent tests are now exempted from the Army body fat circumference-based tape assessment, although their height and weight would still be recorded in their fitness records. This exemption would apply to active duty soldiers for eight months and to Army Reserve and Army National Guard soldiers for 14 months.

Army Directive 2023-11 also directed changes to the method of estimating soldiers' body fat composition (Secretary of the Army, 2023b). The previous multisite circumference-based tape method—in which male soldiers were measured at the waist and neck, and female soldiers were measured at the waist, neck, and hips—will be replaced by a one-site method measuring only waist circumference. The new method is both more accurate and easier to conduct.

Both changes have taken effect too recently for high-quality data to be available for analysis. Soldiers with higher fitness scores face lower average injury risks, whereas soldiers with higher BMI face higher average injury risk (see the discussion in Appendix E). It is unclear how these two divergent indicators will interact. The Army may wish to direct future research toward the population of high-scoring and high-BMI soldiers to monitor and ensure that there is no increased risk of injury for these soldiers.

Injury Documentation and ACFT Exemption Policies

Medical profiles also warrant consideration when examining injury rates in the Army. The Army has two types of medical profiles: permanent profile and temporary profile. Soldiers who have been assigned a permanent profile (with medical conditions documented on DA Form 3349) may be exempt from an individual task or tasks, and those on permanent profile for the 2MR may take one of four alternative ACFT events. The five other events in the ACFT sequence do not have alternatives. Currently, soldiers with a temporary profile are relieved from participating in the entire ACFT until the profile flag is removed (Army Techniques Publication 7-22.01, 2022, p. 2-27). Receiving a permanent-profile marker and an exemption from the 2MR is not a guarantee of ACFT success on other events. Indeed, pass rates for individuals on permanent profile are at least 10 percent lower than soldiers not on permanent profile.[14]

Because we observe test records, our data do not allow us to track the usage of temporary profiles over time, as soldiers on temporary profiles are not authorized to take the ACFT (U.S. Army,

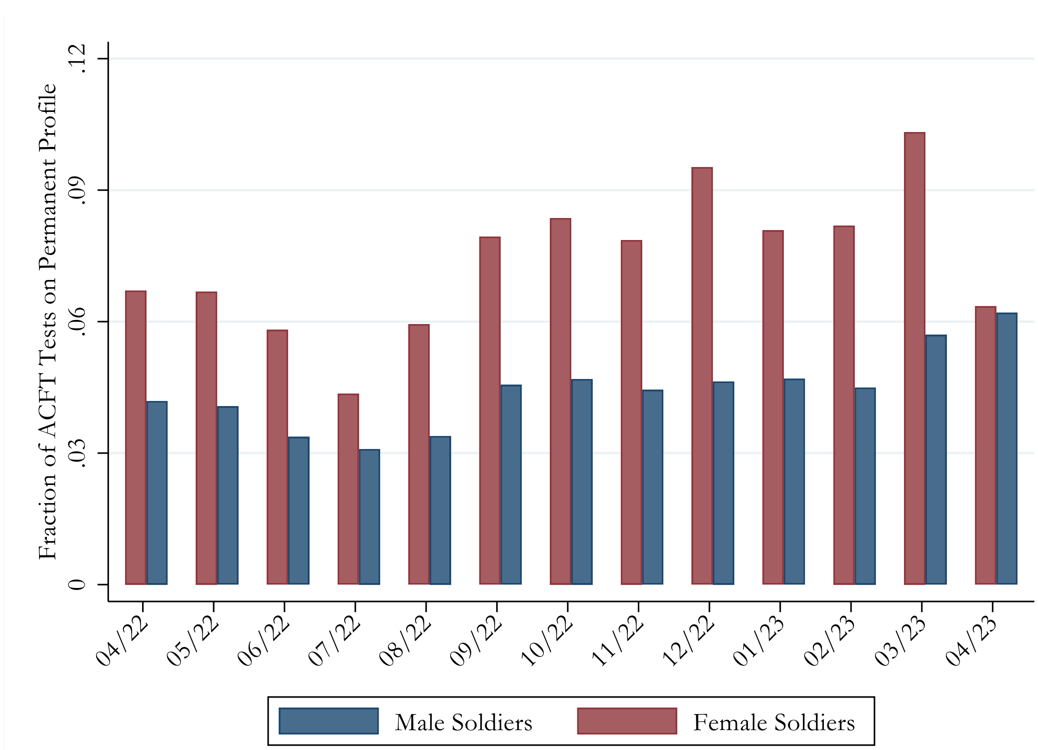
[14] For a more in-depth discussion, see Hicks and Robson, forthcoming.

undated). In this regard, injuries sustained that result in a temporary profile assignment in the window leading up to an ACFT examination could generate downward bias in our estimates of injury risk.

Our data permit an examination of the share of tests for which a permanent profile has been assigned. Figure 2.5 presents the share of ACFTs completed each month since April 2022 that have included permanent-profile status. Although one year is a limited period to draw conclusions, usage of permanent profile has generally increased among both male and female soldiers. It is not possible to directly attribute this to changes in injury rates, however, as many factors may affect aggregate trends.

Indeed, the largest increase is in September 2022, just before testing became for record (on October 1). As a result, the increase in permanent profiles could simply reflect the fact that movement from a diagnostic exam to a for-record-only examination raised the stakes for otherwise injured soldiers who might not have bothered to obtain a permanent-profile status when tests were not completed for record. Additionally, the updates to the electronic profile writing system changing from the APFT events to the ACFT events (given the added breadth of the ACFT events in terms of recruiting different muscle groups) could also explain some of the increased creation of permanent profiles.

Figure 2.5. Trends in Permanent-Profile Usage Among Soldiers Taking the ACFT



SOURCE: Authors' calculations using ACFT dates and injury records provided to RAND by the Army.

Chapter 3

The Relationship Between the ACFT and Injury: Timing and Injury Profile

In this chapter, we describe the data used in the remainder of the report. We then examine injury frequency while training or taking the ACFT and consider relevant risk factors and nuance surrounding ACFT administration.

Data and Study Population

This section describes the health and ACFT data and analysis population.

Health Data

Data on injuries diagnosed were obtained from the Military Health System (MHS) Data Repository (MDR), a data source maintained by DHA. We extracted information on injuries diagnosed in medical files from the MDR to determine injuries sustained by service members based on only the primary-diagnosis code. Appendix A describes this process in more detail.

We used the primary-diagnosis codes to create a variety of indicators that that flagged receipt of a diagnosis for mechanical-energy injuries. To classify diagnosis codes, we applied the APHC injury taxonomy, which does not include diagnosis codes for follow-up care—subsequent or sequela encounters—as new injuries (see, e.g., Hauschild et al., 2021). The data sample provided to RAND for DHA injury data covers the period from 2016 to March 2023, when ICD-10-CM codes were in use consistently.

We examined primary-diagnosis codes for encounters and included up to three acute trauma and up to three cumulative injuries in the 180-day window prior to the ACFT and after the ACFT, leading to an overall count of up to six injuries. This count encompassed the majority of injuries experienced, as relatively few individuals had more than one injury; in practice, less than 10 percent of soldiers suffer a second acute trauma or overuse injury after suffering a first. Nearly all the analysis focuses on whether any injury occurs, not on the total quantity of injuries a soldier suffers.

ACFT Data

ACFT performance records were obtained from the Digital Training Management System (DTMS) and span the period from October 1, 2020, to March 31, 2023. For primary portions of the analysis, we focus on only one test per soldier, completed during the period spanning April 1, 2022, to

October 1, 2022, because the tests taken during this window are representative of the current state of the ACFT and testing policy (i.e., the test could have been used for record and under the current scoring system). Although we have ACFT records beyond October 1, we use those test records for only limited sets of analysis because we have less complete coverage of the injury diagnosis made over the following six months after the test through DHA (which takes time to accumulate these records). Where we use alternative time windows to accommodate characteristics of our data and analysis, these choices are noted with the table or figure.

Although tests between April 1 and October 1, 2022, were considered diagnostic, as discussed in Chapter 1, they were eligible to be considered for record at the start of for-record testing. All soldiers in the Regular Army began taking the ACFT for record as of October 1, 2022. Further, all Regular Army soldiers had to have an ACFT for record by April 1, 2023. On initiation of the for-record regime, Regular Army soldiers must take a for-record ACFT twice per calendar year, with no less than four months between tests. Thus, for many soldiers, it is expected that they will take a for-record test every six months.

Population and Sample Window

We analyzed only the active component. There are multiple reasons for this choice. First, we have some higher-stakes for-record ACFT examinations for this group, as the Army Reserve and National Guard components were implementing the ACFT on a separate timeline. Second, the temporally disjointed nature of reserve component service could lead to imprecision in the estimated impacts of ACFT-related injuries and to reduced statistical specificity in estimating subsequent injury risk using ACFT results. We observed 1,344,301 ACFT administrations, of which 341,961 occurred in our preferred window between April 1, 2022, and October 1, 2022. This window alone covers 286,795 unique soldiers.

It is possible that taking the ACFT itself may lead to injury, and so injuries could be associated with the day of the ACFT. However, soldiers are also likely to train to the ACFT, and that training is likely to align in intensity to the sequencing of for-record testing itself. Thus, if training for the ACFT is associated with injury, it is likely that those injuries will appear in a soldier's medical records in a period leading up to the ACFT.

After soldiers take the ACFT for record, some degree of detraining is anticipated to occur as soldiers focus less on ensuring physical readiness for the ACFT and more on ongoing healthy habits. However, in terms of considering how the ACFT is related to injuries, the four- to six-month period subsequent to the ACFT date is likely to be key.

As a result, in the remainder of our analyses, we regularly divide injury risk analysis into three primary windows of focus:

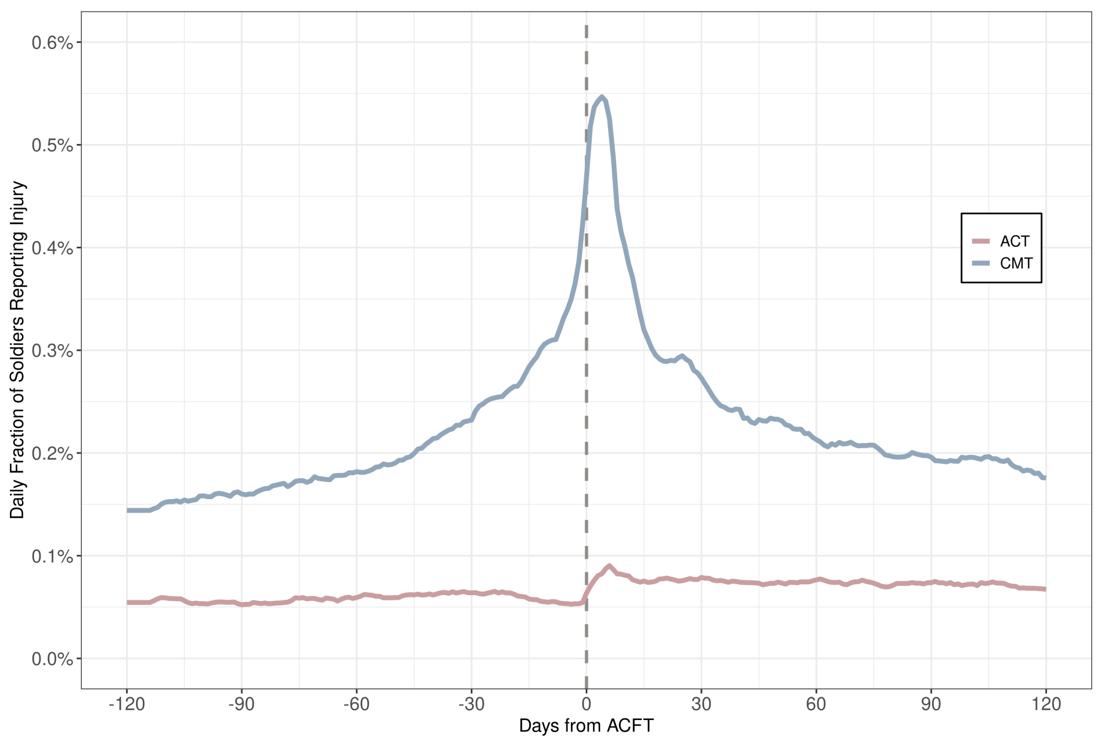
1. **Injuries diagnosed in the six-month period leading up to the ACFT event.** We focus specifically on the proximate windows of time in which soldiers may do their most-intensive preparation.
2. **Injuries diagnosed on the test day or within seven days following the test.** We focus specifically on the window of time in which injuries sustained during test administration would be most likely to appear. This is useful for looking at test-day risk itself.

3. **Injuries diagnosed in the six-month period following an ACFT.** We focus on either (1) the full 180 days after the test to assess test-day and subsequent risk jointly or (2) the period spanning eight to 180 days after the test to estimate the injury risk among Army populations *without* potentially including many injuries resulting from the test itself. This period is useful for addressing how predictive the ACFT could be of baseline injury risk.

The Timing and Frequency of Injuries and the ACFT

In this section, we provide descriptive statistics on the timing, frequency, and composition of observed injuries surrounding the ACFT. Because Army personnel are, at a minimum, required to take the ACFT two times per year, we examined injuries sustained during the six months leading up to an ACFT event and during the six months following test administration. This relationship is depicted in Figure 3.1, which examines observed rates of injury in this window surrounding the ACFT.

Figure 3.1. The Prevalence of Injuries in the Time Window Surrounding ACFT Administration



SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: Prevalence calculations are a moving average of the 12-month window that brackets ACFT records from 180 days before through 180 days after an ACFT is taken. ACT = acute trauma injuries, CMT = cumulative microtrauma or overuse injuries.

Figure 3.1 was not constructed from one exact calendar year but rather is an average of the 12-month window that brackets our ACFT records (180 days before through 180 days after an ACFT is taken). We smoothed injuries over the course of a week using a moving average to reduce visible fluctuations generated by reduced access to medical care over the weekends (and thus clinical presentation of more injury encounters during the workweek).[15] The blue line tracks overuse injuries, and the red line tracks acute trauma injuries.

Several patterns are evident. First, overuse injuries increase as test dates approach. This may reflect an increase in injury rates during training and fitness activity; as soldiers increase their physical fitness levels in training and preparing for the test, their opportunity for injuries also increases. This finding is consistent with a wide range of existing studies which suggest that injury risk increases as individuals start new training programs or increase training levels (Grier et al., 2013). As discussed previously regarding profile status, it is possible that individuals with lingering injuries may be motivated to be seen by a medical professional and put on profile for those injuries prior to taking the ACFT. Notably, there is little discernable increase in the frequency of acute trauma injuries in the run up to the ACFT date.

Beginning on the test date itself and in the days that follow an ACFT administration, injury diagnosis frequency continues to rise and then declines. This pattern is consistent with test taking (and the accompanying increase in physical activity) being associated with higher injury prevalence (approximately three times that of non-ACFT-related time windows). However, one important caveat is that some of this pattern may be an artifact of the time windows of our examination and our data construction. We counted injuries in the lead-up to the ACFT and again in the window following the ACFT. So, as an example, if a soldier comes in for a knee injury because of overuse before the ACFT and after for additional physical therapy, that injury could count in the window before and could still be counted also as a new injury in the period after test administration. Thus, some of the elevated level of injuries observed in the window following the ACFT could be based on counting continued treatment for an issue originally detected in the window prior to the ACFT.[16]

However, we also see a brief increase in the frequency of acute trauma injuries following the ACFT, which, given the timing, are likely to be injuries associated with the ACFT itself. Although it is possible that some of the high frequency of overuse injuries observed in our data result as spillover from the rise in overuse injuries before the test (as previously discussed), that does not account for the observed increase in acute trauma injuries, since there is no corresponding increase in acute injuries before the test.

The rise in injury frequency post-ACFT signals that risk may accrue to the use of the ACFT itself, but some caveats are in order. The ACFT is new, and learning to train for and undertake new physical fitness activities should be expected to carry some degree of injury risk. Thus, this pattern might not continue in the future. We explore this *practice* factor using statistical techniques in the next chapter.

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[15] There is a notable weekly periodicity when using daily injury rates instead of a moving average, which is probably introduced by reduced access to medical care over the weekends. Injuries appear with a clear periodicity around the ACFT test administration and seem to crest close to the midpoint of the week and with a drop over the weekends.

[16] Nevertheless, we focused primarily on injuries in windows of the post-ACFT period for parts of the analysis because the results are not dramatically different using the pre-ACFT window and because the post-ACFT period is less likely to see elevated injury rates as a function of diagnosis among individuals seeking profile status than in the run-up to the test.

The frequency with which individuals take the ACFT is a policy lever that the Army can control. Specifically, the Army could change the frequency with which the test is required to be completed (by altering the length of time under which tests could be kept for record), the policies regarding how frequently soldiers are allowed to take and retake the test, and the policies requiring ACFT administration to individuals in basic combat training or while taking courses. In all these situations, there is a trade-off between developing a culture of fitness and obtaining an up-to-date assessment of soldier abilities and injury risk from increased physical activity.

There is significant variation in the frequency with which soldiers take the test and variation across MOSs, units, installations, components, and demographic groups. For some soldiers, regular testing may incentivize the maintenance of a regular fitness routine that improves health and reduces longer-term injury risk. For other soldiers, sporadic testing could increase injury risk because a soldier may train intensively for each test as it approaches and then ramp down that fitness regimen after, resulting in repeated periods of elevated risk before each test. Finally, as with any physical activity, testing itself will carry some degree of risk, which may be elevated in a high-stakes setting during which individuals may be incentivized to push themselves further than during regular training.

Although it is not simple to weigh these considerations, the Army should develop metrics for assessment and monitoring for each of these benefits and costs and should take them into account in setting policy. The need for assessment and monitoring is particularly true now that a body of for-record ACFT results are being collected.

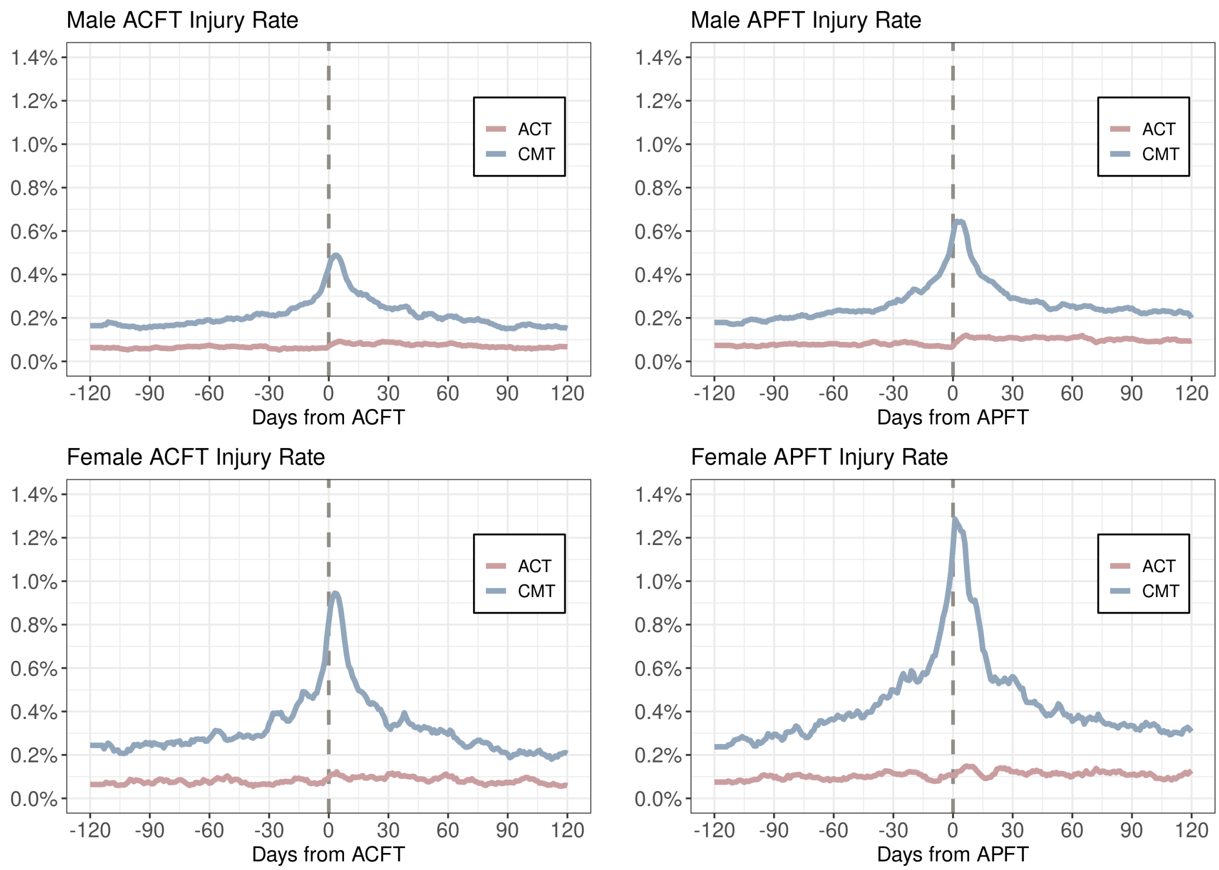
Injury Risk of ACFT Administration: Comparison of APFT Injury Risk with the ACFT

The previous section showed injury counts around the date of ACFT administration. In some cases, the pattern of results may indicate a risk of test administration itself. Given the noted benefits of a regular fitness testing regime for the Army in terms of up-to-date assessments and instilling a culture of fitness, it is relevant to consider whether *any* physical fitness testing regime would impose similar risks. In this section, we compare the observed rate of injuries on the test day and the days surrounding APFT tests (the previous fitness test of record) with the observed rate of injuries on the test day and the days surrounding the ACFT.

To make this exercise as comparable as possible, we restricted the sample in multiple ways to account for the impact of changing physical characteristics and demographics in the military over time. First, we restricted the sample to tests among the enlisted population only. Second, we restricted the sample soldiers ages 17–31 (i.e., those from the first and largest three age groups currently used in scoring for the APFT and ACFT). Third, we excluded soldiers whose BMIs places them in underweight or obese categories to limit the role of changing body mass over time. Fourth, we compared the window of time surrounding APFT tests taken just before the impacts of COVID-19 (April 1, 2018, to September 1, 2019) with ACFTs taken during the most recent same range of calendar months available in our injury data (April 1, 2021, to September 1, 2022). The APFT was the test of record during its window, while the window for the ACFT partially covers the period in which diagnostic tests could be recharacterized for record. As a result, we cannot fully rule out the possibility that injury rates are lower in the ACFT window because of lower motivational effects at play.

As can be seen in Figure 3.2, the relative injury risk of the ACFT does not appear to be any larger for male or female soldiers than under the APFT *when demographics and physical characteristics of the force are held relatively constant.* If anything, injury risk appears lower. This suggests that most physical testing regimes would entail similar risks.

Figure 3.2. Comparison of ACFT and APFT Injury Rates



SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: Please refer to the main text for sample restrictions. ACT = acute trauma injuries; CMT = cumulative microtrauma or overuse injuries.

Nevertheless, several important caveats are noteworthy. First, the behavioral impact of COVID-19 might not be fully accounted for using demographics and body mass restrictions. For example, if people were generally more physically active during the APFT window than during the ACFT window, this difference could change the risk of additional training and testing. Second, soldiers might have treated some of the ACFTs included in this comparison as lower stakes because the time frame includes the diagnostic period; thus, soldiers could have limited effort in ways that affected their relative risk. Third, Army health and fitness programs are not constant over this window. It is not possible in this analysis to isolate the impacts of a program such as H2F—which was in the process of being implemented during the ACFT window but was not implemented during the APFT window—from the direct impacts of the training and testing regimens associated with each assessment.

Medical Care Usage for Injuries and ACFT Administration

Although the prevention of injuries is optimal, fitness activities generally carry some level of injury risk. Given this, the Army can provide soldiers with access to trainers, physical therapists, and other health professionals to ensure that, when injuries do occur, soldiers receive adequate and prompt care. An existing literature has documented that, in some cases, rapid treatment of injuries has several advantages. For example, delayed surgery can raise infection risks (Schepers et al., 2013) and increase the associated hospital and recovery time and lost work time, raising the cost of injuries (Breederveld et al., 1988; Zigenfus et al., 2000) and potentially increasing perceptions of pain posttreatment (Hawkins et al., 2023).

We examined the relationship between the date of administration of the ACFT and the demand for care following a test. We acknowledge a possibility of delay between sustaining an injury and seeking care when medical sites are closed, such as over the weekend. Results from this analysis for the day of week in which an ACFT is administered are presented in Table 3.1. For those with MSKIs (overuse and acute trauma), injuries were reported closer to two days after the ACFT if the test was on a Monday and three and a half to four days if the test was on a Friday. Thus, the Army may wish to consider the days of the week on which the test is administered.

Table 3.1. Day of the Week of ACFT Administration and Demand for Care

Day of the Week on Which the ACFT Is Taken	Days After the ACFT in Which an Injury Is Reported, by Type	
	Overuse	Acute Trauma
Monday	2.21	2.68
Tuesday	2.67	3.09
Wednesday	3.11	3.37
Thursday	3.50	3.53
Friday	3.77	3.54
Saturday	3.65	3.33
Sunday	2.67	3.09

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The results are for ACFTs taken between October 1, 2020, and January 1, 2023. The sample consists of only those soldiers receiving a medical diagnosis in the first seven days after they took the ACFT.

Counts and Rates of Injuries and ACFT Administration

Table 3.2 presents counts and rates of injuries, both before and after an ACFT date and by gender. Both males and females are approximately 3 percentage points less likely to report acute or cumulative injuries on the day of or up to 180 days after an ACFT relative to the 180 days before the test. This implies that the test itself is not a strong driver of injuries. There are multiple potential causes of the increase in overuse prior to the ACFT, which we cannot deconflict in the data. First, soldiers may be increasing their injury risk by training in preparation for of the ACFT. Second, the appearance of injury may be a signal that soldiers are being seen for nagging injuries so that they have a profile at the time of testing. This may serve to mitigate the increased risk of injury that the test itself may otherwise pose. Our data include a profile only if a soldier was awarded permanent profile in this window, as soldiers with temporary profiles were not taking the ACFT and therefore would not appear as a record in our data.

Table 3.2. Counts and Rates of Traumatic and Overuse Injuries

	180 Days Leading Up to the ACFT			ACFT Date and 180 Days Following		
Injury	**All**	**Males**	**Females**	**All**	**Males**	**Females**
Acute trauma injury (occurrences, at least 1, 2, or 3)						
1	8.89%	8.69%	10.16%	9.75%	9.59%	10.72%
2	1.06%	1.05%	1.17%	1.39%	1.35%	1.64%
3	0.15%	0.15%	0.15%	0.24%	0.24%	0.26%
Overuse injury (occurrences, at least 1, 2, or 3)						
1	27.67%	26.51%	34.86%	29.03%	27.94%	35.84%
2	7.58%	7.01%	11.11%	8.47%	7.93%	11.84%
3	2.01%	1.82%	3.21%	2.41%	2.23%	3.51%
At least one injury (acute trauma or overuse)						
	31.69%	30.55%	38.77%	33.12%	32.08%	39.56%

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.

NOTE: Includes only the most recent ACFT taken by soldiers in the window from April 1, 2022, to January 1, 2023. The sample size is 327,183 tests. The first three acute trauma injuries are shown (up to three), as are the first three overuse injuries (up to three). In practice, less than 10 percent of soldiers suffered a second acute trauma or overuse injury after suffering a first.

Table 3.3 presents the breakdown of injuries by *general* body region. Although many of the pre- and posttest differences are statistically significant because of large sample sizes, none is of sufficient magnitude to warrant a closer look. However, there are significant differences in the male and female injury rates for acute trauma and cumulative trauma (overuse) by region of injury. Women are significantly more likely to suffer lower-extremity injuries than their male counterparts; whereas men are correspondingly more likely to suffer upper-extremity injuries. This relationship is both statistically significant ($p < 0.001$) and relatively large in magnitude (4–6 percentage points for acute trauma injuries and 5–8 percentage points for overuse injuries). Such differences may warrant consideration and attention by medical personnel and personnel in charge of developing and implementing unit physical training progression, as the finding suggests somewhat different injury profiles by gender that may be related to the ACFT or training for the ACFT.

Table 3.3. Counts and Rates of Injuries by General Body Region

	180 Days Leading up to the ACFT				ACFT Date and 180 Days Post-ACFT			
Injury Category	**Observations**	**All**	**Males**	**Females**	**Observations**	**All**	**Males**	**Females**
Acute trauma	**30,390**				**26,725**			
Head and neck	5,917	19%	19%	20%	4,693	18%	18%	18%
Lower extremity	11,690	38%	38%	41%	10,339	39%	38%	44%
Spine and back	2,308	8%	7%	9%	2,149	8%	8%	9%
Torso	1,638	5%	5%	6%	1,437	5%	5%	5%
Upper extremity	8,727	29%	30%	24%	7,990	29%	30%	24%
Other	110	0%	0%	0%	117	0%	0%	0%
Cumulative trauma	**90,130**				**83,298**			
Head and neck	2,826	3%	3%	1%	2,587	3%	3%	1%
Lower extremity	41,734	47%	46%	52%	37,243	46%	45%	53%
Spine and back	27,537	30%	31%	30%	26,428	31%	32%	29%
Torso	70	0%	0%	0%	52	0%	0%	0%
Upper extremity	16,579	18%	19%	15%	15,671	18%	19%	14%
Other	1,384	2%	2%	2%	1,317	2%	2%	2%

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The sample consists of only the most recent ACFT taken by soldiers in the window from April 1, 2022, to October 1, 2022. The sample size is 327,183 tests. The table presents injuries observed for given body regions; a given soldier could have up to three acute trauma injuries and up to three overuse injuries across body regions and hence register as an observed injury up to six times. In practice, less than 10 percent of soldiers suffered a second acute trauma or overuse injury after suffering a first. Values less than 0.5 percent are rounded to 0.

Table 3.4 presents the breakdown of injuries by specific body region for upper and lower extremities. As in Table 3.3, there are no major variations in pre- and post-ACFT injury rates. There are, however, significant differences between male and female populations in specific injury locations, with females more likely to suffer hip injuries and males more likely to suffer shoulder injuries. These differences hold for both acute and cumulative trauma. This result suggests that the injury risks before and after an ACFT may vary to some degree by gender, reflecting differences in training regimens between the two windows of time and possibly risk from the test itself.

Table 3.4. Counts and Rates of Injuries by Specific Body Region

Injury Category	180 Days Leading up to the ACFT				ACFT Date and 180 Days Post-ACFT			
	Observations	All	Males	Females	Observations	All	Males	Females
Acute trauma	**20,581**				**22,784**			
Ankle	3,105	15%	15%	18%	3,302	14%	14%	16%
Foot, toe	2,271	11%	11%	13%	2,516	11%	11%	14%
Hip	918	4%	4%	6%	1,057	5%	4%	9%
Knee	2,057	10%	10%	9%	2,455	11%	11%	10%
Leg, lower	2,055	10%	10%	11%	2,304	10%	10%	11%
Leg, other	71	0%	0%	0%	85	0%	0%	0%
Leg, upper	1,160	6%	6%	5%	1,327	6%	6%	5%
Arm, lower	1,124	5%	5%	5%	1,282	6%	6%	5%
Arm, other	28	0%	0%	0%	21	0%	0%	0%
Arm, upper	395	2%	2%	2%	455	2%	2%	1%
Elbow	784	4%	4%	3%	847	4%	4%	3%
Hand, finger	3,883	19%	19%	16%	3,941	17%	18%	14%
Shoulder	2,052	10%	10%	7%	2,470	11%	11%	7%
Wrist	678	3%	3%	3%	722	3%	3%	3%
Cumulative trauma	**61,415**				**63,693**			
Ankle	7,733	13%	13%	12%	7,050	11%	11%	11%
Foot, toe	8,000	13%	13%	14%	8,431	13%	13%	14%
Hip	5,679	9%	7%	17%	6,182	10%	8%	18%
Knee	17,042	28%	28%	25%	18,113	28%	29%	27%
Leg, lower	3,519	6%	6%	5%	3,844	6%	6%	6%
Leg, other	1,214	2%	2%	2%	1,041	2%	2%	2%
Leg, upper	1,029	2%	2%	2%	997	2%	2%	2%
Arm, lower	163	0%	0%	0%	194	0%	0%	0%
Arm, other	324	1%	1%	0%	315	0%	1%	0%
Arm, upper	101	0%	0%	0%	94	0%	0%	0%
Elbow	1,590	3%	3%	1%	1,669	3%	3%	1%
Hand, finger	2,400	4%	4%	3%	2,469	4%	4%	3%
Shoulder	9,336	15%	16%	11%	9,972	16%	17%	11%
Wrist	3,285	5%	5%	6%	3,322	5%	5%	5%

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The sample consists of only the most recent ACFT taken by soldiers in the window from April 1, 2022, to October 1, 2022. These are injuries observed for given body regions; a given soldier could have up to three acute trauma injuries and up to three overuse injuries across specific body regions and hence register as an observed injury up to six times. In practice, less than 10 percent of soldiers suffered a second acute trauma or overuse injury after suffering a first. Values less than 0.5 percent are rounded to 0.

Chapter 4

The Relationship Between the ACFT and Future Injury Risk

In this chapter, we consider demographic, occupational, environmental, and physiological factors that may affect the level of risk faced by Army personnel. We first run a set of univariate regressions so we can articulate various potential influence factors on injury rates. After examining these variables in isolation, we examine the extent to which the ACFT may be used to help predict (and hopefully prevent) injury risk (through interventions and related investments). For these analyses, our regressions control for a variety of demographic, physical, and temporal characteristics associated with an individual and their test date, and we present separate analyses by gender. We do not restrict to for-record tests in the primary analysis (only in robustness tests) because the majority of these tests are recent enough that information on the injuries observed in the period following these tests could lack complete coverage.

In general, we employ Cox regressions (survival analysis) because they explicitly account for information about the time to injury. In this way, survival analysis can be used to demonstrate injury risk *at any point in time* over a specified window for the populations at risk. Thus, given our interest in the timing of injury, this analysis offers a richer approach to examining injury risk. Hazard ratios of less than 1 indicate a decreased risk relative to the reference group, whereas those over 1 indicate an increased risk relative to the reference group.

Injury Risk Factors

In this section, we explore the relationship between the ACFT and injury risk across demographic, physical, and occupational characteristics and observed injuries sustained in the window of time around the ACFT.

Injury Risk by Demographic Group

We first undertook a set of univariate Cox regressions (survival analysis) to document the relative risk associated with different demographic groups and physical characteristics. These analyses should be considered as descriptive and noncausal. For simplicity of exposition, in Table 4.1, we compare the relative risk of specific demographic groups against those from a baseline group for each of these categories (the baseline group in each group has a hazard ratio of 1 and a notation of *Ref* in the standard-error column). The relevant dependent variable is *all injury*—that is, injury regardless of whether it is overuse or acute trauma.

Table 4.1. Injury Risk by Demographics and Physical Characteristics (Univariate)

Variable	Male Soldiers Sample Size	Male Soldiers Proportion Injured	Male Soldiers Hazard Ratio	Male Soldiers Standard Error	Female Soldiers Sample Size	Female Soldiers Proportion Injured	Female Soldiers Hazard Ratio	Female Soldiers Standard Error
Age								
17–21	50,907	0.27	0.96***	0.01	8,868	0.40	1.26***	0.03
22–26	75,901	0.29	1	*Ref*	12,531	0.36	1	*Ref*
27–31	51,586	0.30	1.06***	0.01	8,095	0.37	1.08***	0.03
32–36	33,209	0.33	1.17***	0.01	5,037	0.41	1.15***	0.03
37–41	21,477	0.40	1.56***	0.02	3,146	0.47	1.40***	0.04
42+	13,978	0.46	1.92***	0.03	2,060	0.51	1.68***	0.06
Marital status								
Single	105,684	0.28	1	*Ref*	16,952	0.39	1	*Ref*
Married	118,647	0.34	0.69***	0.10	19,189	0.40	1.01	0.21
Race/ethnicity								
Black, not Hispanic	42,220	0.35	1.14***	0.02	11,268	0.43	1.22***	0.04
White, not Hispanic	123,245	0.30	0.92	0.01	13,332	0.37	0.96	0.03
Hispanic	40,369	0.32	1.01	0.02	7,727	0.40	1.04	0.03
Other	18,631	0.30	1	*Ref*	3,877	0.38	1	*Ref*
CDC BMI								
Underweight	680	0.28	1.02	0.07	265	0.37	0.86	0.09
Normal	66,052	0.28	1	*Ref*	18,661	0.38	1	*Ref*
Overweight	118,182	0.32	1.21***	0.01	15,009	0.41	1.20***	0.02
Obese	44,710	0.37	1.45***	0.02	2,438	0.47	1.46***	0.05
Army BMI								
Underweight	680	0.28	1.02	0.07	265	0.37	0.86	0.09
Normal	66,052	0.28	1	*Ref*	18,661	0.38	1	*Ref*
Low overweight	70,462	0.31	1.16***	0.01	9,801	0.40	1.16***	0.02
High overweight	47,720	0.33	1.28***	0.01	5,208	0.43	1.28***	0.03
Obese	44,710	0.37	1.45***	0.02	2,438	0.47	1.46***	0.05
Height								
Bottom 25%	77,447	0.32	1.00	0.01	12,579	0.39	0.96	0.03
25–50%	36,951	0.31	1	*Ref*	5,601	0.39	1	*Ref*
50–75%	56,145	0.31	1.01	0.01	9,887	0.39	1.00	0.03
75–100%	59,081	0.32	1.03**	0.01	8,306	0.41	1.04	0.03

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: Sample size varies by specification. Hazard ratios should be interpreted as risk relative to the reference category. The data cover ACFTs taken between October 2020 and October 2022. We conducted a survival analysis using the Cox proportional hazard model. Marital status other and missing BMI data categories are not shown. Each panel is a separate regression with one categorical variable only. The analysis window spans day of test through 180 days posttest. CDC = Centers for Disease Control and Prevention; *Ref* = reference (the reference, or omitted, category for a categorical variable).
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

As can be seen from Table 4.1, injury risk among active duty personnel increases with age. Specifically, male soldiers who are 42 and older are 92 percent as likely to suffer an injury as those ages 22 to 26, which we used as our comparison category. For female soldiers, the relative age-risk gradient does not appear as sharp, with those who are 42 and older approximately 68 percent more likely to suffer an injury. Younger females (ages 17 to 21) are also at a significantly higher risk of injury compared with those ages 22 to 26, in contrast to the lower injury risk faced by younger males in a similar comparison. Although we do not know the precise reasons for this relative risk difference, potentially some of this divergence may be explained by differential risk responses to initial training by gender.

Risk for male soldiers differs depending on marital status. Married men are 31 percent less likely to suffer an injury than single men with similar demographic characteristics. The cause of the large and marked divergence is unclear, but the increase in injury risk between single and married male cohorts is equivalent to that between normal and obese cohorts. Our analysis found no relationship between marital status and injury risk for female soldiers.

In comparison to a reference category of *other race and ethnicity* (comprising unknown race and ethnicity, American Indian or Alaska Native, and Asian and Pacific Islander), Hispanic soldiers and White non-Hispanic soldiers do not exhibit a difference in risk for injury. In contrast, Black non-Hispanic soldiers (both male and female) are approximately 14 to 22 percent more likely to suffer an injury.

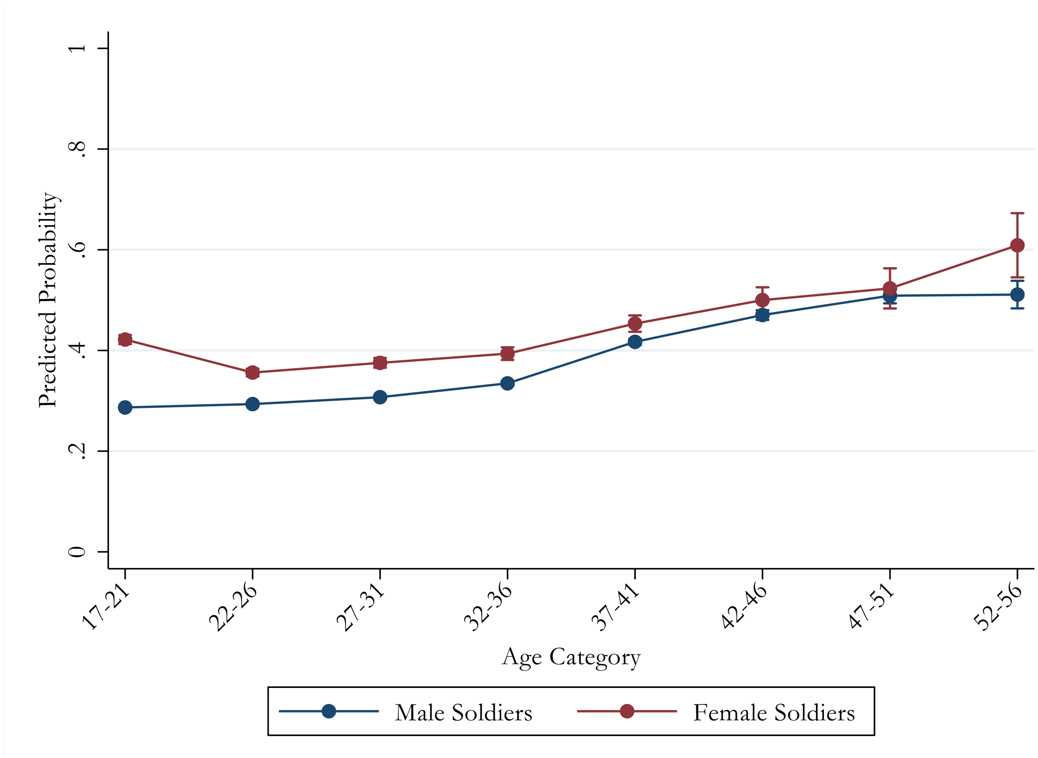
Echoing the literature, we found a linear relationship between BMI and injury risk. As soldiers increased in BMI, their risk of injury increased. This is true using the CDC BMI categories and the Army BMI categories, which bifurcate *overweight* into *low overweight* and *high overweight*.

The last panel of Table 4.1 shows that male soldiers at the highest quartile in height are more at risk of injury than soldiers in the second quartile. The comparison, although relatively small in effect size, is significant.

We further illustrate some of these findings in Figures 4.1 and 4.2. Figure 4.1 shows the predicted probability of an injury (for both acute trauma and overuse injuries) across all the ACFT age bins through the use of a logistic regression that also controls for other factors.[17] Unlike the survival analysis, which compares the relative injury hazard across groups, this exercise presents the estimated probability that an individual suffers any injury at any point in the six-month period after the ACFT. As the figure illustrates, injury risk increases with age for both male and female soldiers. Figure 4.2 displays injury risks by Army BMI category even after controlling for ACFT age groupings and shows that risk of injury increases along with the increase in body mass from category to category.

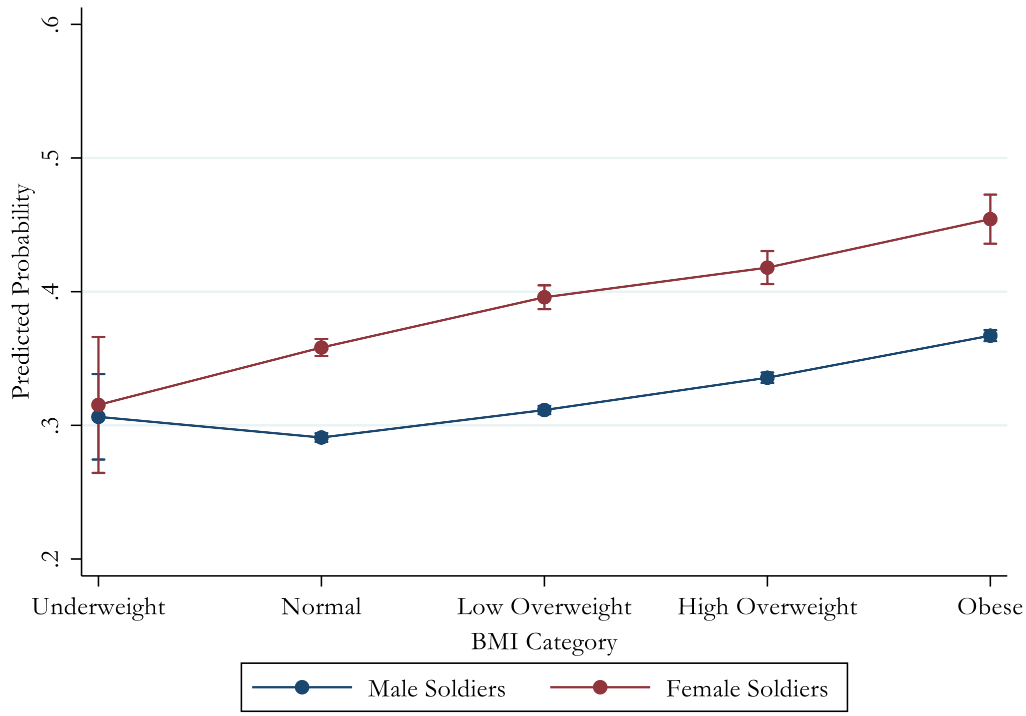
[17] In this exercise, we calculated predicted probabilities after running a logistic regression that additionally controls for body composition group, day of the week of the test, and month of the test.

Figure 4.1. Predicted Probability of an Injury Across All ACFT Age Bins



SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The data are from ACFTs taken between April 2022 and October 2022. A logistic regression with robust standard errors is depicted. The analysis includes any acute trauma or overuse injury suffered from test date through 180 days following an ACFT.

Figure 4.2. Injury Risk by BMI Category



SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The data are from ACFTs between April 2022 and October 2022. A logistic regression with ACFT age group controls and robust standard errors is depicted. The analysis includes any acute trauma or overuse injury suffered from the test date through 180 days following an ACFT.

Injury Risk by Occupational Characteristics

In Table 4.2, we compare the relative injury risk across specific Army populations. Here, we focus less on traditional demographics in favor of a brief foray into injury risk across occupational characteristics. Occupational demands expose soldiers to a wide variety of physical activities. We investigate the relative risk during the 180 days leading up to an ACFT of being in basic training, being in a combat MOS, and being in each Occupational Physical Aptitude Test (OPAT) MOS occupational tiering (heavy, significant, moderate). We also investigate the relative risk to enlisted and officers, as well as to those on profile. As in the prior table, relative risk of specific groups is compared against those from a baseline group for each of these categories (the baseline group in each group has a hazard ratio of 1 and a notation of *Ref* in the standard-error column). Unlike the prior analysis, all factors are considered simultaneously, with controls included for demographic and physical characteristics.

Table 4.2. Injury Risk by Army Occupational Characteristics (Multivariate)

	Male		Female	
Occupational Characteristic	**Hazard Ratio**	**Standard Error**	**Hazard Ratio**	**Standard Error**
In basic training	1.21***	0.03	1.53***	0.08
Not in basic training	1	*Ref*	1	*Ref*
Enlisted	1.40***	0.02	1.39***	0.03
Warrant officer	0.66***	0.06	0.98	0.20
Officer	1	*Ref*	1	*Ref*
Combat MOS	0.81***	0.01	0.92	0.05
Non-combat MOS	1	*Ref*	1	*Ref*
OPAT (moderate)	1	*Ref*	1	*Ref*
OPAT (heavy)	1.05***	0.01	1.06*	0.04
OPAT (significant)	0.99	0.01	1.00	0.02
Not on profile	1	*Ref*	1	*Ref*
Profile flag in DTMS	1.36***	0.02	1.43***	0.04
Number of observations	221,813		35,475	

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.

NOTE: The data are from ACFTs taken between April 2022 and October 2022. We conducted a survival analysis using the Cox proportional hazard model. We include a control for BMI category, ACFT age group, month of test, and day of the week of the test. The analysis window spans eight days through 180 days following the test. *Ref* = reference (the reference, or omitted, category for a categorical variable).

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Our results shows that some occupational characteristics are significantly associated with injury incidence in the active component, even when we condition on selected physical and demographic characteristics. Soldiers engaged in intensive physical experience of being in basic training are at greater risk of injury than those who are not in basic training, to the tune of approximately 20 percent (for males) to 50 percent (for females) risk of injury. Enlisted personnel are nearly 40 percent more likely than officers to be injured in a six-month period. Individuals in combat MOSs are less likely to suffer an injury, although this is statistically significant only for male soldiers. Lower risk may reflect the selection of healthier soldiers into these occupations, and an observed lower risk during 2022 might not be reflective of injury risk faced by soldiers in combat MOSs during periods of increased deployment and major Army operations. Additionally, individuals in heavy MOS categories appear to be at greater risk of injury relative than those in other OPAT categories.[18] We also examine profile status as a consideration for injury risk, even though profile status does not describe a difference in occupation or job situation per se. Compared with soldiers without a permanent-profile flag in DTMS (and controlling for a variety of temporal and demographic characteristics), soldiers on permanent profile at the time of the test are also more likely to suffer injury in the window of time after an ACFT.

Injury Risk Gradients Within an Occupational Category

The physical demands of Army MOSs vary. We examined injury risk as a function of age and BMI categories for groupings of occupations. Varied occupational demands could create different gradients with respect to these factors, and that information could help Army decisionmakers identify those at risk or target resources. Figures 4.3 and 4.4 display predicted injury risk for male and female soldiers, respectively, by ACFT age category among soldiers in each of the heavy, moderate, and significant OPAT MOS categories.

As the figures indicate, injury risk increases with age in all three MOS categories. Among male soldiers, injury risk is slightly higher in moderate and significant MOSs than in the heavy MOS. Nevertheless, injury risk appears to increase at relatively the same gradient with age for all three categories, suggesting that, as soldiers age, there is no *increased* relative risk from being in more physically demanding MOSs, when compared with being in less physically demanding MOSs. Similar gradients exist for BMI categories, but differences across BMI categories for the three MOS categories are not significantly different from one another either.

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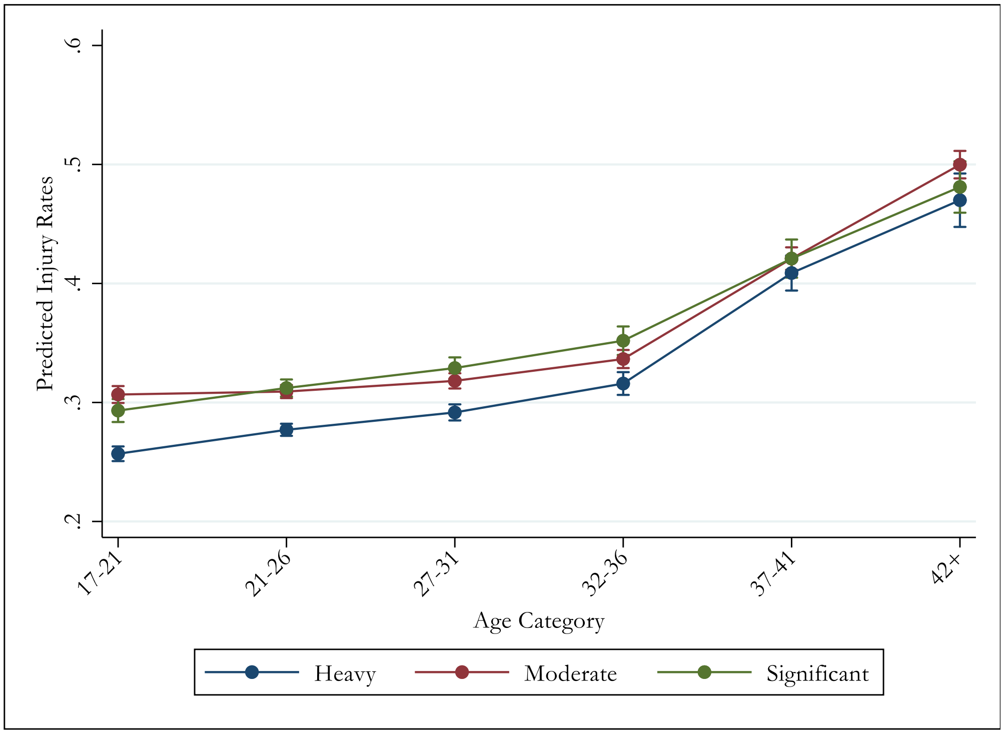
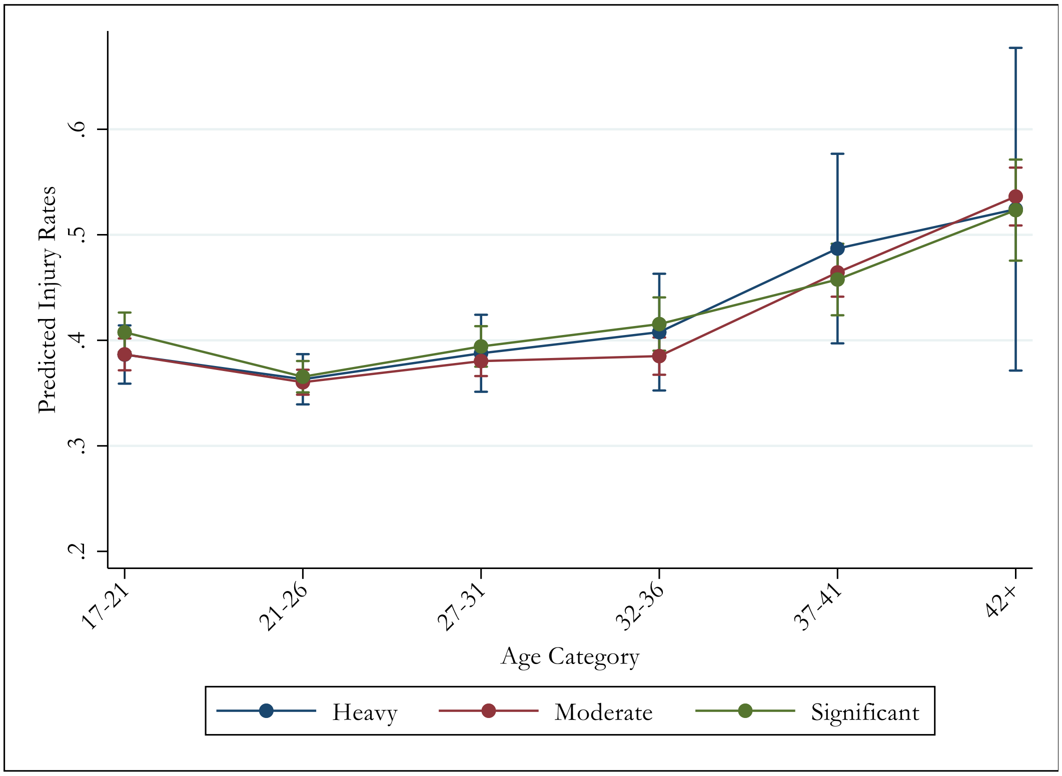
[18] In unconditional regressions, moderate and significant OPAT categorizations are associated with a 36 to 38 percent increase in injury risk.

Figure 4.3. Predicted Injury Risk for Male Soldiers by Age Among OPAT MOS Categories



SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The data are from ACFTs taken between April 2022 and October 2022. A logistic regression with robust standard errors is depicted. We include a control for permanent-profile status, BMI category, month of test, and day of the week of test. The analysis includes any acute trauma or overuse injury suffered seven days through 180 days following the test.

Figure 4.4. Predicted Injury Risk for Female Soldiers by Age Among OPAT MOS Categories



SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The data are from ACFTs taken between April 2022 and October 2022. A logistic regression with robust standard errors is depicted. We include a control for permanent-profile status, BMI category, month of test, and day of the week of test. The analysis includes any acute trauma or overuse injury suffered seven days through 180 days following the test.

The Role of Test Experience on Injury Risk

Existing literature has documented that undertaking new physical fitness training and training to a higher level of fitness is associated with elevated risk of injury. But once those routines are established, injury risk should decline, with a potential exception for particularly strenuous physical fitness activities, such as deployment in combat (see Grier et al., 2013). We included in our analysis an examination of the injury risk associated with additional experience with the ACFT. ACFT administration is, as should be expected, associated with some degree of elevated injury risk because of the accompanying increase in physical activity and potentially because of the high-stakes nature of how the test results are used.

At the same time, if soldiers gain experience with the test or if they change training regimes to better acclimatize to a new or more appropriate training program for the muscle groups tested, then we might also expect to see a lower injury risk from subsequent tests.[19] Given that the ACFT was explicitly designed to engage additional muscle groups and hence encourage more-holistic training, a decline in injury risk would be an indication of the successful implementation of the culture-of-fitness goal.

In Figure 4.5, we present the results of examining the likelihood of sustaining an injury while taking the ACFT, using survival analysis.[20] First ACFT events are treated as the reference category, so the hazard rates for injury risk presented in the figure are relative to the first test, with values below 1 suggesting a reduction in injury risk. Our results show that injury risk declines with each subsequent attempt of the ACFT for at least the first three tests (statistically significantly so) and possibly for additional tests beyond these. Specifically, the estimates imply that, for male soldiers, injury risk is 10 percent lower on a second attempt relative to the first and 16 percent lower on the third test than the first test. The reduction in injury risk for female soldiers is even larger. Moving from the first to second attempt is associated with a decline in the relative hazard of 15 percent, and moving from the first to the third is associated with a reduction in risk of 29 percent.

These patterns suggest that, as the force gains experience with the ACFT, injury rates may continue to fall, although this effect should ultimately plateau and depend on the rate of new entrants to the Army relative to the duration of tenure for soldiers in the Army (i.e., the proportion of soldiers experienced with the test).

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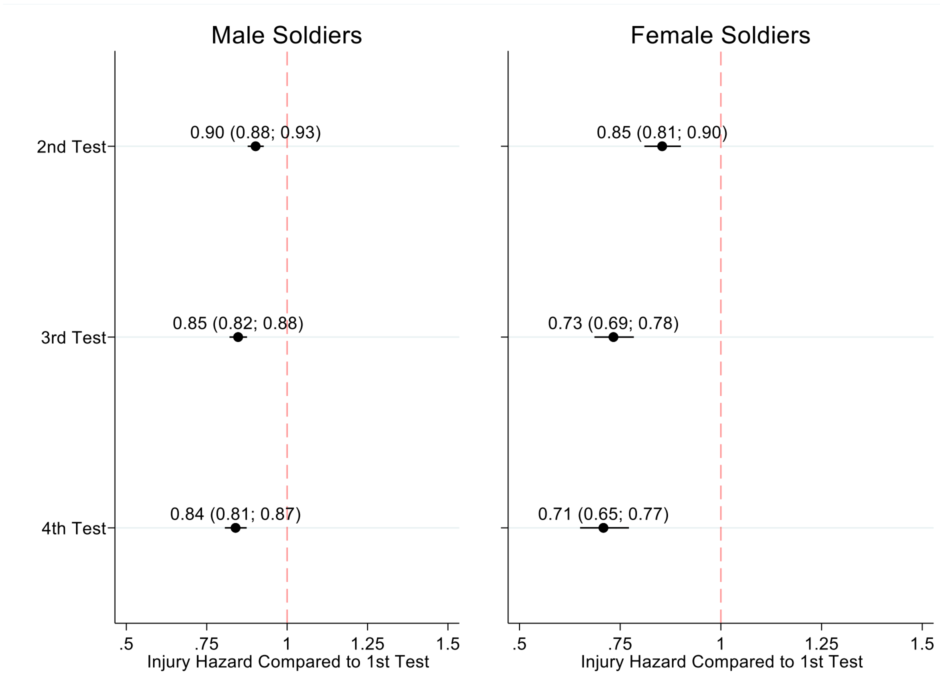
19 An important distinction is that we are not able to separately identify some of the underlying mechanisms driving this relationship. With each attempt of the ACFT, soldiers gain both increased training history over time and direct experience taking the test. Likely, both mechanisms matter. Specifically, additional training history with these physical fitness activities lowers injury risk as soldiers become familiar with the movements that are part of the events, and experience taking the ACFT could lower risk from attempting the events on the test day.

20 We proxied for test-day risk using injuries diagnosed on the day of the ACFT day or within the first week after the test itself in case there were delays in realizing the severity of an injury or delays in seeking treatment. As discussed previously, injuries spike on the test day and remain elevated for a short period following the test. We cannot explicitly parcel out injuries resulting from the ACFT itself from injuries sustained in the immediate few days after the test without this information being collected at the time of the test or in clinical intake. To balance these considerations, we selected a one-week window under the assumption that this range is most likely to capture test-day injuries as precisely as possible in our data.

Figure 4.5. Injury Risk by Test Attempt



SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The reference group is soldiers' first tests. Values above 1 imply greater relative risk; values below 1 imply lower risk. The data are from ACFTs taken between October 2020 and January 2023. We conducted a survival analysis using the Cox proportional hazard model. Robust standard errors are in parentheses. We include a control for permanent-profile status, indicators for rank category (i.e., officer, enlisted, warrant), BMI category, ACFT age group, month of test, and day of the week of the test. The analysis window spans injuries sustained on the test day through seven days following the test.

How Predictive Is ACFT Performance of Subsequent Injury Risk?

In this section, we explore the relationship between performance on the ACFT and subsequent injury risk.

Overall ACFT Performance and Injury Risk

We observed multiple measures of ACFT performance in DTMS. We examined the relationship between pass-fail rates and overall ACFT score and subsequent injury risk. We modeled this analysis separately for male and female soldiers because both physiological and performance differences might imply different relationships between observed performance and injury risk for each population. To assess this relationship, we made several simplifying assumptions and took multiple empirical approaches to identify nuances in the observed injury pattern.

There are several approaches to examining the predictive relationship between fitness assessment and injury risk. In many studies, a probit or logit model is used to capture the probability that individuals with a set of characteristics (such as low or high performers on a test or different demographic groups) suffer an injury over a fixed window of time, as in many of the studies included in our literature review (see Appendix E). These approaches calculate the probability that an injury event occurs over a set window regardless of when that injury is sustained within the window. An advantage of this approach is the simplicity of the estimates produced and the ease of interpretation. The disadvantage is the approach discards useful information—specifically, performance on a physical fitness assessment may predict future injury at different rates for different periods in the future (for instance, individuals detrain some muscle groups faster than others, cardiovascular fitness tends to detrain faster than muscular strength, or some groups of individuals face differential rates of risk over subsequent months).

First, we computed the predicted probability of an individual soldier suffering a mechanical injury at any time during the six months following an ACFT as a function of these performance measures (ACFT overall score and ACFT raw event scores).[21] As demonstrated previously, important risk factors for injury include age, gender, and BMI categorization. For these reasons, we included controls in the analysis for ACFT age groups and BMI categories, and we calculated results separately for male and female soldiers.[22] We also included flexible time controls to capture the average impact of taking the ACFT under different policies (for record, not for record) and controlled for the day of the week of the test.

Table 4.3 presents the results of this analysis. In comparison to the group that received "narrowly passing" scores on the ACFT total score (360–419), groups that had higher ACFT total scores had a lower risk of any injury. Those who failed the ACFT, in contrast, were about 20 percent more likely to suffer an injury. This pattern holds true for overuse injuries when separated from acute trauma. However, males who scored at the highest level on the ACFT were approximately 10 percent more likely than males who narrowly passed the test to suffer an acute trauma in the subsequent months. Both men and women who failed the ACFT were more likely than those who narrowly passed to suffer acute trauma in the subsequent six months following their ACFTs—with women approximately 16 percent more likely to suffer acute trauma MSKIs and with men being 21 percent more likely.

It is possible that this general pattern of results could be differentiated depending on the general body region examined. However, as shown in Table 4.4, for the most part, those who narrowly passed the ACFT had a higher risk of overuse injury than groups that scored higher overall. Specifically, those who failed the ACFT were generally at higher risk than those who narrowly passed of overuse injuries for all general body regions, except for head and neck (in this category, soldiers who failed the ACFT were not significantly different from those who narrowly passed the ACFT). Those with higher scores on the total ACFT were less at risk of overuse injuries in all general body regions than those who narrowly passed the ACFT, with few exceptions.

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[21] As a robustness check, we also computed these probabilities through a series of logistic regressions with similar findings. Appendix B provides additional detail regarding the empirical strategy employed. For this analysis, we excluded injuries sustained on the test day and the week following to assess the predictive relationship between fitness scores and future injury risk (rather than the injury risk of the test-taking process itself).

[22] It is important to remember that the observed impacts are conditional (i.e., the hazard rates reflect the association of the ACFT with injuries, after accounting for a variety of other factors that influence injury risk). Appendix B presents details on the empirical framework used to estimate the survival analysis in this section and displays coefficients on these controls for the primary analysis tables.

Table 4.3. The Association Between the ACFT and Subsequent Injury Risk by Injury Type

	All Injuries		Overuse Injuries		Acute Trauma Injuries	
ACFT Score	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Fail	1.26***	1.22***	1.29***	1.26***	1.21***	1.16***
	(0.02)	(0.04)	(0.02)	(0.04)	(0.03)	(0.06)
360–419	1	1	1	1	1	1
	Ref	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
420–479	0.94***	0.93***	0.93***	0.94**	0.99	0.99
	(0.01)	(0.02)	(0.01)	(0.03)	(0.02)	(0.05)
480–539	0.93***	0.91***	0.92***	0.90***	1.04	1.02
	(0.01)	(0.03)	(0.01)	(0.03)	(0.02)	(0.05)
540–600	0.93***	0.87***	0.91***	0.86***	1.10***	0.96
	(0.01)	(0.03)	(0.01)	(0.03)	(0.03)	(0.07)
Number of observations	235,932	37,038	237,292	37,288	245,402	39,406

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The reference category for the ACFT score is 360 to 419. The data include the most recent ACFT for soldiers between April 2022 and October 2022. We conducted a survival analysis using the Cox proportional hazard model, with hazard ratios presented and robust standard errors in parentheses. We include a control for permanent-profile status, indicators for rank category (i.e., officer, enlisted, warrant), BMI category, ACFT age group, month of test, and day of the week of the test. The analysis window spans eight days through 180 days following the test. *Ref* = reference (the reference, or omitted, category for a categorical variable).
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Table 4.4. The Association Between the ACFT and Subsequent Overuse Injury Risk by General Body Region

ACFT Score	Head and Neck		Spine and Back		Upper Extremity		Lower Extremity		Torso and Other	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Fail	0.96	1.05	1.31***	1.25***	1.40***	1.37***	1.36***	1.33***	1.48**	1.60*
	(0.08)	(0.21)	(0.07)	(0.10)	(0.09)	(0.16)	(0.03)	(0.05)	(0.22)	(0.40)
360–419	1	1	1	1	1	1	1	1	1	1
	Ref	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
420–479	0.94	1.11	0.83***	0.79***	0.90*	0.84*	0.94***	0.95	0.66***	0.96
	(0.05)	(0.18)	(0.03)	(0.06)	(0.05)	(0.09)	(0.02)	(0.03)	(0.08)	(0.21)
480–539	0.88**	1.07	0.80***	0.75***	0.94	0.75**	0.92***	0.90***	0.69***	0.80
	(0.05)	(0.20)	(0.03)	(0.06)	(0.05)	(0.09)	(0.02)	(0.03)	(0.09)	(0.20)
540–600	0.83***	0.49**	0.77***	0.51***	0.93	0.75*	0.89***	0.82***	0.58***	0.90
	(0.06)	(0.14)	(0.04)	(0.06)	(0.06)	(0.12)	(0.02)	(0.04)	(0.09)	(0.30)
Number of observations	242,915	38,432	242,915	38,432	242,915	38,432	242,915	38,432	242,915	38,432

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The reference category for the ACFT score is 360 to 419. The data are from the most recent ACFT for soldiers between April 2022 and October 2022. We conducted a survival analysis using the Cox proportional hazard model, with hazard ratios presented and robust standard errors in parentheses. We include a control for permanent-profile status, indicators for rank category (i.e., officer, enlisted, warrant), BMI category, ACFT age group, month of test, and day of the week of the test. The analysis window spans eight days through 180 days following the test. *Ref* = reference (the reference, or omitted, category for a categorical variable).
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Specific Event Performance and Injury Risk

In addition to examining the risk of injury relative to overall ACFT performance, we examined the relationship between specific event performance and injury risk. We follow each event in the order they are performed during the test. It is useful to examine each ACFT event because the events test different muscle groups and body systems. Each event is captured in a different metric (e.g., the MDL performance is pounds lifted, with greater pounds indicating greater performance, whereas the SDC performance is seconds to completion, with fewer seconds indicating greater performance). In this regard, the relationship examined is between event performance and injury risk, relative to all other performances, rather than relative to soldiers in the same age group. We approached this analysis in multiple ways.

First, we examined performance quantiles for each event using raw performance values to construct these groups (Table 4.5). We used the third quantile, or middling performance on each event, as our comparison group. This ensured that our comparison was typical, rather than extreme, performance. As before, when looking at the overall ACFT, many of the soldiers with the lowest scores on individual events have a higher risk of injury. For some events, including the HRP (for both males and females) and the 2MR (for males), the risk of injury decreases as performance increases.

However, for some events and particularly for male soldiers, we see that injury risk increases with higher performance as well. The effect size is largest for the SPT, in which male soldiers in the fifth quantile have about an 8 percent increased risk of injury compared with male soldiers in the third quantile.

Table 4.5. Quantiles of Raw Event Performance and Subsequent Soldier Injury Risk

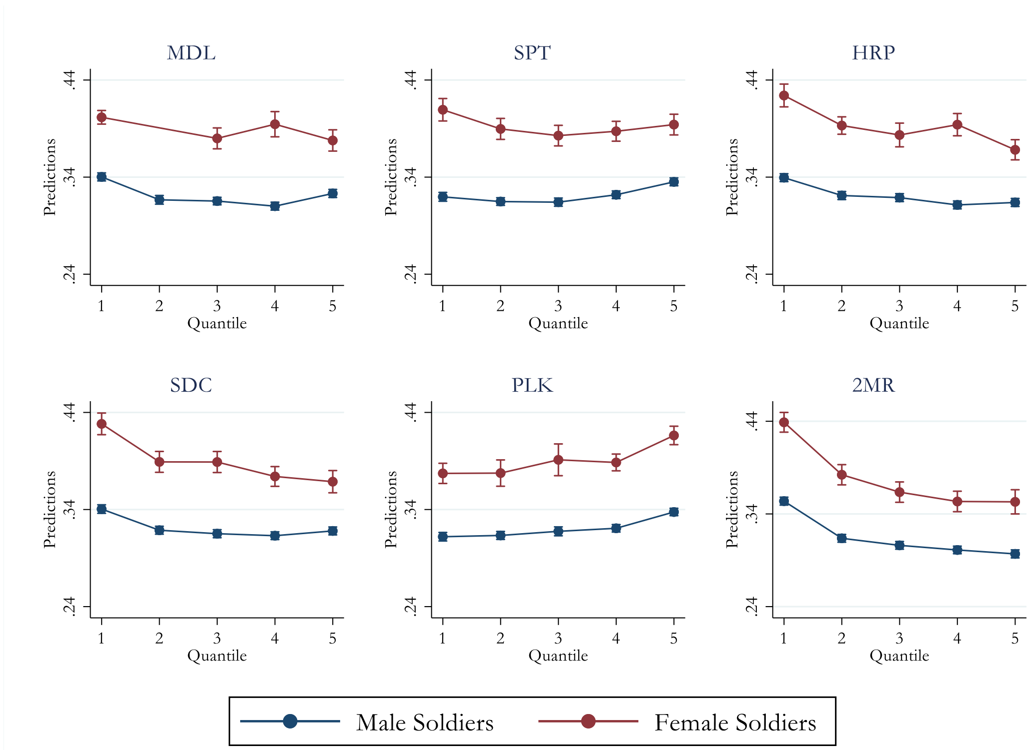
	MDL		SPT		HRP	
	Male	Female	Male	Female	Male	Female
1st quantile (lowest)	1.08***	1.02	1.01	1.09***	1.06***	1.10***
	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)
2nd quantile	1.00	0.95	1.00	1.02	1.00	1.02
	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)
3rd quantile	1	1	1	1	1	1
	Ref	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
4th quantile	0.97**	0.94*	1.02*	1.02	0.97***	1.03
	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)
5th quantile (highest)	1.03**	See	1.08***	1.04	0.98**	0.93**
	(0.01)	Note	(0.01)	(0.03)	(0.01)	(0.03)

	SDC		PLK		2MR	
	Male	Female	Male	Female	Male	Female
1st quantile (lowest)	1.08***	1.13***	0.98	0.94*	1.17***	1.23***
	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)
2nd quantile	1.01	1.01	0.98	0.94	1.03**	1.05*
	(0.01)	(0.03)	(0.01)	(0.04)	(0.01)	(0.03)
3rd quantile	1	1	1	1	1	1
	Ref	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
4th quantile	1.00	0.97	1.01	0.97	0.98	0.96
	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)
5th quantile (highest)	1.02	0.95*	1.06***	1.06*	0.97***	0.95
	(0.01)	(0.03)	(0.01)	(0.04)	(0.01)	(0.03)

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The reference group is the third quantile. Female soldier MDL scores are clustered such that some quantiles contain many ties, preventing estimation. Quartiles are used instead with the third quartile as reference. The data are from ACFTs taken between April 2022 and October 2022. We conducted a survival analysis using the Cox proportional hazard model. Robust standard errors are in parentheses. We include a control for permanent-profile status, indicators for rank category (i.e., officer, enlisted, warrant), BMI category, ACFT age group, month of test, and day of the week of the test. The analysis window spans eight days through 180 days following the test. The number of observations varies slightly by regression but is approximately 230,000 for male soldiers and 36,000 for female soldiers. *Ref* = reference (the reference, or omitted, category for a categorical variable).
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

These results are visually depicted in Figure 4.6, which presents predicted probabilities of injury across each of the raw performance bins. Note that these quantiles are computed separately for male and female soldiers, depicted by blue and red lines, respectively.

Figure 4.6. Subsequent Soldier Injury Risk Plotted by Quantiles of Raw Event Performance



SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The data are from ACFTs taken between April 2022 and October 2022. A logistic regression with robust standard errors is depicted. We include a control for permanent-profile status, BMI category, month of test, and day of the week of test. The analysis includes any acute trauma or overuse injury suffered seven days through 180 days following the test. For male soldiers, the confidence intervals are hard to discern because they are very small, indicating more precision in the estimates.

We next turn to an examination of event performance scores, using the group with a narrowly passing score as the comparison group.

The MDL

Performance on the MDL is significantly associated with subsequent injury across multiple tiers of performance, shown in Table 4.6. A few findings stand out:

- Failure on the MDL event is significantly associated with higher injury risk for both acute trauma and overuse injuries.
- Performance in higher deciles of event scoring is associated with reduced risk for overall injuries, with this effect driven by a decrease in overuse injuries.

- Performance in the highest-scoring groups for both men and women is associated with an increased risk of acute trauma injuries. This outcome could suggest a small relative injury risk increase (~8 percent) to both male and female soldiers from attempting to reach the highest-scoring tiers of the MDL event.

Table 4.6. Association Between MDL Scoring and Injury Risk

	All Injuries		Overuse Injuries		Acute Trauma Injuries	
MDL Event Score	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
<60 (event fail)	1.35***	1.26***	1.37***	1.27***	1.29***	1.24*
	(0.08)	(0.10)	(0.08)	(0.10)	(0.12)	(0.16)
60–69	1	1	1	1	1	1
	Ref	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
70–79	0.94***	0.99	0.92***	1.00	0.99	1.04
	(0.01)	(0.02)	(0.01)	(0.03)	(0.02)	(0.05)
80–89	0.91***	1.00	0.89***	0.99	1.01	1.07
	(0.01)	(0.03)	(0.01)	(0.04)	(0.02)	(0.07)
90–100	0.93***	0.95**	0.91***	0.94**	1.08***	1.08*
	(0.01)	(0.02)	(0.01)	(0.03)	(0.02)	(0.05)
Number of observations	235,932	37,038	237,292	37,288	245,402	39,406

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The data are from ACFTs taken between April 2022 and October 2022. We conducted a survival analysis using the Cox proportional hazard model. Robust standard errors in parentheses. We include a control for permanent-profile status, indicators for rank category (i.e., officer, enlisted, warrant), BMI category, ACFT age group, month of test, and day of the week. The analysis window spans eight days through 180 days following the test. *Ref* = reference (the reference, or omitted, category for a categorical variable).
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

The SPT

As shown in Table 4.7, performance on the SPT is significantly associated with subsequent injury across multiple tiers of performance. A few findings stand out:

- Failure on the SPT event is significantly associated with higher injury risk for both acute trauma and overuse injuries for men—but only overuse injuries for women.
- The SPT is rather anomalous when compared with other ACFT events. Unlike the other events, higher deciles of event scoring is not associated with reduced risk for overall injuries.
- Performance in the highest-scoring groups is associated with an increased risk of both overuse and acute trauma injuries for men.
- Improved SPT performance is associated with increased risk for men even after repeating this exercise and controlling for height, which prior work has shown as an advantage to SPT performance (Hicks and Robson, forthcoming).

Table 4.7. Association Between SPT Scoring and Injury Risk

SPT Event Score	All Injuries Male	All Injuries Female	Overuse Injuries Male	Overuse Injuries Female	Acute Trauma Injuries Male	Acute Trauma Injuries Female
<60 (event fail)	1.20***	1.24***	1.24***	1.26***	1.13**	1.10
	(0.04)	(0.06)	(0.04)	(0.07)	(0.06)	(0.10)
60–69	1	1	1	1	1	1
	Ref	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
70–79	1.01	0.97	1.01	0.96	1.03	0.98
	(0.01)	(0.02)	(0.01)	(0.03)	(0.02)	(0.04)
80–89	1.01	0.98	1.00	0.99	1.09***	1.00
	(0.01)	(0.02)	(0.01)	(0.03)	(0.02)	(0.05)
90–100	1.07***	1.00	1.06***	1.01	1.22***	1.04
	(0.01)	(0.02)	(0.01)	(0.03)	(0.02)	(0.05)
Number of observations	235,932	37,038	237,292	37,288	245,402	39,406

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The data are from ACFTs taken between April 2022 and October 2022. We conducted a survival analysis using the Cox proportional hazard model. Robust standard errors are in parentheses. We include a control for permanent-profile status, indicators for rank category (i.e., officer, enlisted, warrant), BMI category, ACFT age group, month of test, and day of the week of test. The analysis window spans eight days through 180 days following the test. *Ref* = reference (the reference, or omitted, category for a categorical variable).
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

The HRP

As shown in Table 4.8, performance on the HRP is significantly associated with subsequent injury across multiple tiers of performance. A few findings stand out:

- Failure on the HRP event is significantly associated with higher injury risk for both acute trauma and overuse injuries. The strength of this association is larger in magnitude than for any of the other five events.
- The HRP exhibits a performance injury risk gradient, with higher performances associated with lower injury risk.
- Unlike the SPT and the MDL, there is no evidence that higher performance on the HRP is associated with greater injury risk in any category.

Table 4.8. Association Between HRP Scoring and Injury Risk

HRP Event Score	All Injuries		Overuse Injuries		Acute Trauma Injuries	
	Male	Female	Male	Female	Male	Female
<60 (event fail)	1.45***	1.30***	1.48***	1.33***	1.37***	1.24*
	(0.09)	(0.09)	(0.09)	(0.10)	(0.14)	(0.15)
60–69	1	1	1	1	1	1
	Ref	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
70–79	0.92***	0.97	0.92***	0.99	0.95**	0.96
	(0.01)	(0.03)	(0.01)	(0.03)	(0.02)	(0.04)
80–89	0.91***	0.95**	0.91***	0.94**	0.95**	0.92*
	(0.01)	(0.02)	(0.01)	(0.03)	(0.02)	(0.04)
90–100	0.90***	0.89***	0.90***	0.89***	0.96**	0.94
	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)	(0.05)
Number of observations	235,932	37,038	237,292	37,288	245,402	39,406

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The data are from ACFTs taken between April 2022 and October 2022. We conducted a survival analysis using the Cox proportional hazard model. Robust standard errors are in parentheses. We include a control for permanent-profile status, indicators for rank category (i.e., officer, enlisted, warrant), BMI category, ACFT age group, month of test, and day of the week of test. The analysis window spans eight days through 180 days following the test. *Ref* = reference (the reference, or omitted, category for a categorical variable).
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

The SDC

Performance on the SDC is significantly associated with subsequent injury across multiple tiers of performance, as shown in Table 4.9. A few findings stand out:

- Failure on the SDC event is significantly associated with higher injury risk for both acute trauma and overuse injuries.
- The SDC exhibits an injury risk gradient, with higher performances associated with lower injury risk, mostly for overuse injuries.
- The highest-performing male soldiers on the SDC are at slightly higher risk for acute trauma injuries.

Table 4.9. Association Between SDC Scoring and Injury Risk

	All Injuries		Overuse Injuries		Acute Trauma Injuries	
SDC Event Score	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
<60 (event fail)	1.28***	1.30***	1.33***	1.33***	1.15***	1.17*
	(0.04)	(0.06)	(0.04)	(0.07)	(0.06)	(0.10)
60–69	1	1	1	1	1	1
	Ref	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
70–79	0.93***	0.95*	0.92***	0.94**	0.97	0.98
	(0.01)	(0.03)	(0.01)	(0.03)	(0.02)	(0.05)
80–89	0.93***	0.92***	0.91***	0.91***	0.99	0.94
	(0.01)	(0.02)	(0.01)	(0.03)	(0.02)	(0.05)
90–100	0.93***	0.90***	0.91***	0.88***	1.07***	0.99
	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)	(0.05)
Number of observations	235,932	37,038	237,292	37,288	245,402	39,406

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.

NOTE: The data are from ACFTs taken between April 2022 and October 2022. We conducted a survival analysis using the Cox proportional hazard model. Robust standard errors are in parentheses. We include a control for permanent-profile status, indicators for rank category (i.e., officer, enlisted, warrant), BMI category, ACFT age group, month of test, and day of the week of test. The analysis window spans eight days through 180 days following the test. *Ref* = reference (the reference, or omitted, category for a categorical variable).

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

The PLK

As shown in Table 4.10, performance on the PLK is significantly associated with subsequent injury across multiple tiers of performance. A few findings stand out:

- Failure on the PLK event is significantly associated with higher injury risk for both acute trauma and overuse injuries.
- Stronger performance on the PLK is associated with lower future risks for overuse injuries but not for acute trauma injuries. This is in contrast to the examination of raw PLK performance in Table 4.5. The critical difference is that comparing soldiers across scoring outcomes, as in Table 4.10, rather than raw PLK times in the previous analysis, means that high-performance tiers reflect fitness excellence *relative to soldiers of the same gender and approximately the same age*, rather than fitness outcomes relative to all other soldiers.

Table 4.10. Association Between PLK Scoring and Injury Risk

	All Injuries		Overuse Injuries		Acute Trauma Injuries	
PLK Event Score	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
<60 (event fail)	1.33***	1.31***	1.38***	1.34***	1.25***	1.32***
	(0.04)	(0.06)	(0.04)	(0.06)	(0.06)	(0.10)
60–69	1	1	1	1	1	1
	Ref	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
70–79	0.95***	0.98	0.95***	0.97	0.97	1.06
	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)	(0.04)
80–89	0.93***	0.95*	0.92***	0.94*	0.99	1.07
	(0.01)	(0.03)	(0.01)	(0.03)	(0.02)	(0.06)
90–100	0.95***	0.93***	0.94***	0.92***	1.02	0.97
	(0.01)	(0.03)	(0.01)	(0.03)	(0.02)	(0.05)
Number of observations	235,932	37,038	237,292	37,288	245,402	39,406

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The data are from ACFTs taken between April 2022 and October 2022. We conducted a survival analysis using the Cox proportional hazard model. Robust standard errors are in parentheses. We include a control for permanent-profile status, indicators for rank category (i.e., officer, enlisted, warrant), BMI category, ACFT age group, month of test, and day of the week. The analysis window spans eight days through 180 days following the test. *Ref* = reference (the reference, or omitted, category for a categorical variable).
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

The 2MR

As Table 4.11 shows, performance on the 2MR is significantly associated with subsequent injury across multiple tiers of performance. A few findings stand out:

- Failure on the 2MR event is significantly associated with higher injury risk for both acute trauma and overuse injuries.
- The 2MR exhibits the strongest performance injury risk gradient of any event, with higher performances associated with lower injury risk.
- Lower levels of injury risk associated with 2MR performance are from reductions in overuse injuries among these populations.

Table 4.11. Association Between 2MR Scoring and Injury Risk

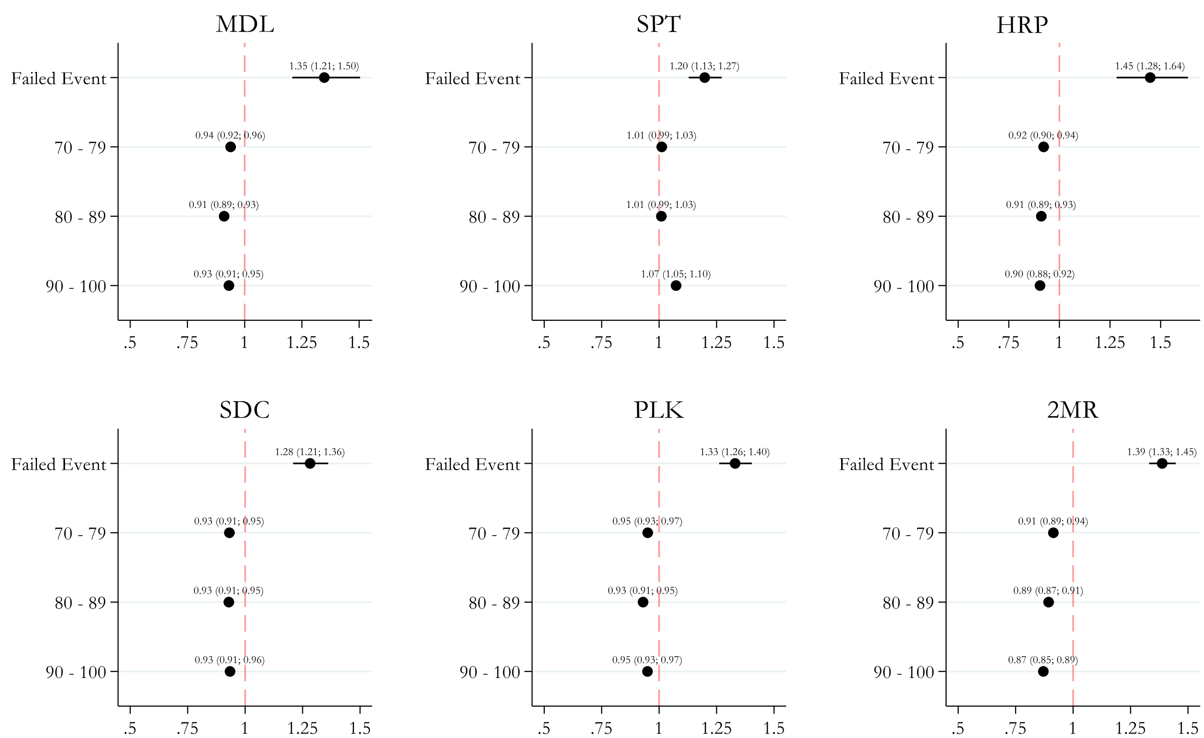
	All Injuries		Overuse Injuries		Acute Trauma Injuries	
2MR Event Score	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
<60 (event fail)	1.39***	1.28***	1.42***	1.31***	1.30***	1.24***
	(0.03)	(0.04)	(0.03)	(0.05)	(0.05)	(0.08)
60–69	1	1	1	1	1	1
	Ref	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
70–79	0.91***	0.91***	0.90***	0.90***	0.96*	1.03
	(0.01)	(0.02)	(0.01)	(0.03)	(0.02)	(0.05)
80–89	0.89***	0.88***	0.87***	0.87***	0.98	0.96
	(0.01)	(0.02)	(0.01)	(0.03)	(0.02)	(0.05)
90–100	0.87***	0.85***	0.84***	0.83***	0.97	0.98
	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)	(0.05)
Number of observations	235,932	37,038	237,292	37,288	245,402	39,406

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The data are from ACFTs taken between April 2022 and October 2022. We conducted a survival analysis using the Cox proportional hazard model. Robust standard errors are in parentheses. We include a control for permanent-profile status, indicators for rank category (i.e., officer, enlisted, warrant), BMI category, ACFT age group, month of test, and day of the week of test. The analysis window spans eight days through 180 days following the test. *Ref* = reference (the reference, or omitted, category for a categorical variable).
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Comparison Across Events

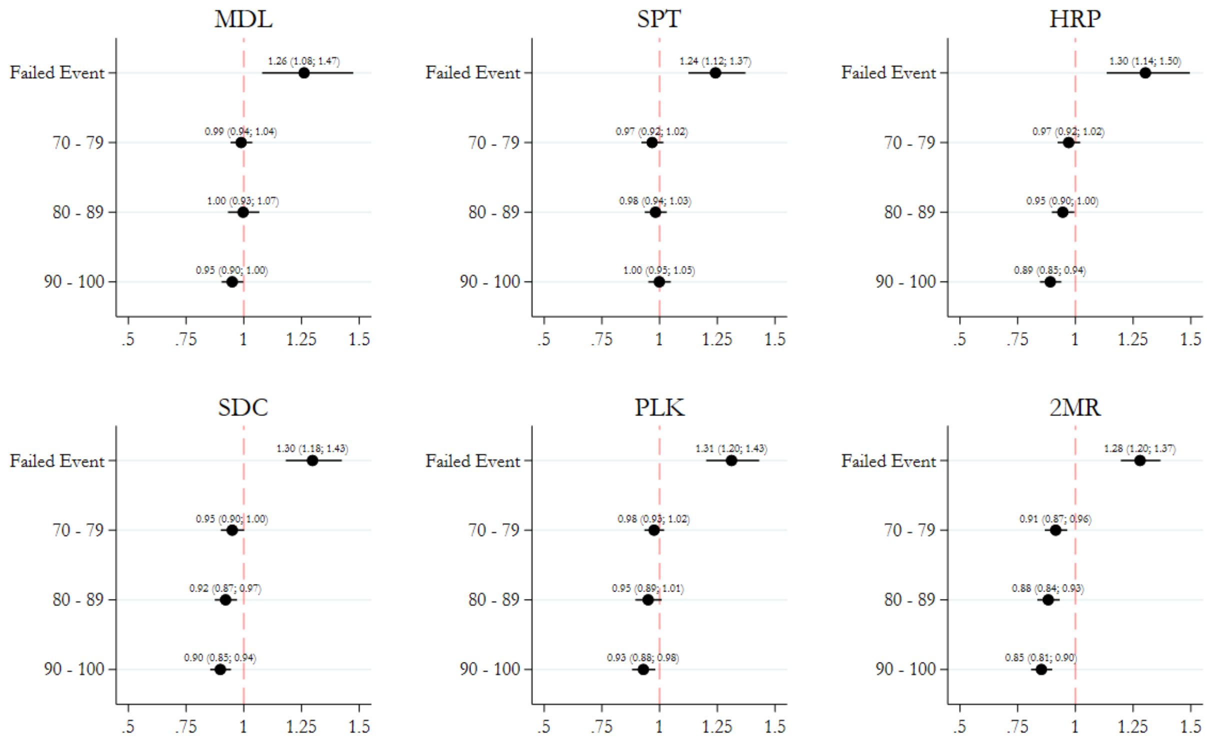
To illustrate the impact of event performance on injury risk more clearly, we plotted the hazard ratios from the event-by-event tables in Figure 4.7 and Figures 4.8 for male and female soldiers, respectively. In each figure, soldiers scoring between 60 and 69 on the event are treated as the reference category, which is depicted by the dashed red line. Then, each coefficient presented represents the relative injury risk among soldiers who have either failed the event or scored in higher-scoring ranges on the event. These figures make clear that the 2MR exhibits perhaps the clearest gradient of improved performance, aligning with lower injury risk, and Figure 4.7 shows the anomalous nature of high performance on the SPT and injury risk for men.

Figure 4.7. Event Performance and Injury Risk for Male Soldiers



SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The reference groups are soldiers scoring 60 to 69 on each event. Values above 1 imply greater relative risk; values below 1 imply lower risk. For example, 1.35 for failing the MDL would suggest that an individual is at 35 percent higher injury risk than those scoring 60 to 69. The data are from ACFTs taken between April 2022 and October 2022. We conducted a survival analysis using the Cox proportional hazard model. CIs (95 percent) are in parentheses. We include a control for permanent-profile status, indicators for rank category (i.e., officer, enlisted, warrant), BMI category, ACFT age group, month of test, and day of the week of test. The analysis window spans eight days through 180 days following the test.

Figure 4.8. Event Performance and Injury Risk for Female Soldiers



SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The reference groups are soldiers scoring 60 to 69 on each event. Values above 1 imply greater relative risk; values below 1 imply lower risk. For example, 1.26 for failing the MDL would suggest that an individual is at 26 percent higher injury risk than those scoring 60 to 69. The data are from ACFTs taken between April 2022 and October 2022. We conducted a survival analysis using the Cox proportional hazard model. CIs (95 percent) are in parentheses. We include a control for permanent-profile status, indicators for rank category (i.e., officer, enlisted, warrant), BMI category, ACFT age group, month of test, and day of the week of test. The analysis window spans eight days through 180 days following the test.

Chapter 5

Conclusions and Recommendations

This report presents a preliminary evaluation of the relationship between the ACFT and health—specifically, injuries. This final chapter provides a summary of the findings and suggests potential ACFT policy actions that the Army could take to help reduce preventable injuries, assess and monitor soldiers at risk, and inform relevant Army stakeholders.

The Army is engaged in a suite of initiatives, including H2F, that is intended to emphasize the importance of a holistic approach to physical fitness, balance physical fitness with other domains (such as mental, spiritual, and sleep fitness), and help establish what the Army terms a *culture of fitness* and encourage mental toughness and stamina. Our research focus was primarily on one initiative, the ACFT, whose stated goals not only include the establishment of that culture of fitness and enhancement of mental toughness and stamina but also an improvement in readiness and—our specific emphasis—a reduction in injuries.

It is difficult to see how the ACFT alone can be said to directly implement the first two goals. However, because the ACFT is a broad physical fitness assessment with requirements to train for a wider variety of physical capabilities, preparation for the test requires a more general adoption of a range of training activities that enhance not just cardiorespiratory fitness but also fitness components, such as muscular strength, power, and agility. To the extent that this range of fitness activities is undertaken as preparation for regular testing, it may enhance a culture of fitness and a physically ready force more broadly. More generally, fitness is associated with a myriad of benefits. Injury reduction is also associated with increased fitness (this association is strongest for cardiorespiratory fitness; see reviews in de la Motte et al., 2017; de la Motte et al., 2019; Lisman et al., 2017).

Notwithstanding the association in the literature between fitness and injury reduction, the relationship between the ACFT and injury warrants empirical support. As noted, the ACFT may encourage a more holistic approach to fitness, but the primary relationship supported in the literature is between cardiorespiratory fitness and health. Although holistic fitness components, such as muscular strength, power, and agility, may have other benefits, the longer-term relationship of the ACFT to health and injury is not as clear.

The ACFT itself may be expected to initially increase injuries to the extent that soldiers undertake a new training regimen and learn new activities. Specifically, soldiers may be subject to injuries associated with both ramping up training and engaging in new forms of training (Grier et al., 2013). As described in the *2022 Health of the Force* report, running was one of the explicit causes to which lost duty days was most often attributed, at 27 percent (U.S. Army, 2022). Strength training was also in the top five reported causes, at 8 percent. Moreover, injuries may be associated not just with preparation for the test but with the test itself, especially when the test is a new experience for many. However, over the longer term, if the ACFT's stated goal of overall injury reduction is met—as might be anticipated by the literature—there is great potential to reduce costs for the Army in terms of medical treatment costs and of readiness and longer-term outcomes, such as disability discharge (Molloy, Pendergrass, Lee, Chervak, et al., 2020).

To determine the empirical relationship between the ACFT and injuries, we reviewed the literature on the associations between fitness testing and injury rates. We additionally reviewed existing surveillance information. We also combined ACFT data with data on medical encounters and examined reported injury rates across the Army and during both the APFT regime and the rollout of the ACFT.

The timing of ACFT administration was strongly associated with injury risk. Our data showed a distinct increase in overuse injuries prior to the test date, although acute trauma injuries remained at a relatively constant rate during this time. However, this finding does not necessarily mean that soldiers were more likely to incur an overuse injury during the period in which they were preparing for the ACFT. Rather, it is possible that soldiers might have proactively chosen to seek care for existing nagging injuries and potentially go on profile prior to taking the test.

We did observe a brief spike in acute trauma injuries when looking at the test date and for several days into the 180-day window following the test date. However, we compared the windows 180 days prior to and following the test for the ACFT with similar APFT time windows and noted that the profile of injury experience for the ACFT was not notably different from that for the APFT. Together, these findings suggest that administration of the ACFT itself is not a substantially greater injury risk than any other general fitness testing, although it should be noted that our data rely on injuries severe enough to be observed in the military health system—that is, injuries severe enough to warrant a medical encounter.

We also observe injury patterns that suggest that soldiers may be delaying treatment for injuries when the test is run on Friday or Saturday, relative to early in the week. We also see some differences in location of injury by gender, with females more likely to suffer hip injuries and males more likely to suffer shoulder injuries. These patterns warrant continued observation and may be targets for intervention.

Our analysis suggests that the ACFT is a highly predictive test when assessing injury risk. With regard to the ACFT as a whole, groups that scored higher on the ACFT overall had significantly lower risk of any injury than the group that received "narrowly passing" total scores on the ACFT (360–419). Those who failed the ACFT, in contrast, were about 20 percent more likely to suffer an injury in the 180-day window following the ACFT. This pattern is driven mostly by risk of overuse injuries, although acute trauma risk is also associated. Thus, better performance on the ACFT is associated with reduced risk of injury.

Most of the test components of the ACFT also showed strong associations with future injury risk when considered individually. Consistent with prior research that finds higher cardiorespiratory fitness to be associated the most strongly with lower injury risk (Lisman et al., 2017), cardiorespiratory activities exhibited some of the strongest positive associations between performance and reduced injury risk. However, passing the strength events of the ACFT was also associated with reduced risk.[23] In general, the patterns found for the overall ACFT held (i.e., event failure was

[23] Although the strongest fitness associations have been observed between injury risk and aerobic capacity (Lisman et al., 2017; Lovalekar et al., 2021), additional fitness characteristics, including muscular strength, have also been linked to lower injury risk in prior research (e.g., de la Motte et al., 2017).

associated with a higher risk of injury, whereas better event performance was associated with a lower risk, particularly of overuse injury). At the same time, performance at the highest-scoring tiers for the MDL for men and women and the SDC and the SPT for men was associated with higher acute trauma risk.

To the extent that broader, more holistic training is indeed motivated by the more expansive requirements of the ACFT, the literature suggests that the ACFT may in some sense lead to an overall reduction in injuries. Further monitoring of injuries, especially compiled with information on actual training programs, would help bolster this conclusion.

We investigated the H2F rollout to determine whether an effect on MSKIs was observed in our data, but, given the limited nature of the rollout at the time of this research, we determined that it was too early to draw firm conclusions. However, some of the stated objectives of the ACFT are more clearly implemented through the H2F intervention, which uses expert personnel and expertise to optimize physical fitness training programs and additional equipment to facilitate that optimization. Physical therapists, strength coaches, and other personnel will help implement the intent of injury avoidance. Cognitive performance experts are intended to facilitate the resilience and "mental toughness" goals. Because of the effort entailed in the dispersion of personnel and materiel for this initiative and the phased rollout, careful attention to desired outcomes and to the collection of related data throughout the rollout is warranted and would also facilitate assessment of ACFT goals.

A few additional points are of note. First, test dates immediately prior to or during the weekend are associated with a longer interval before a soldier appears in the medical encounter data, suggesting that the weekend may encourage a lag in being seen for an injury. Immediate care can prove beneficial, so the active component Army might want to schedule its ACFT dates near the beginning of the week, if the costs to doing so are low. Second, we observed a clear effect of practice on the ACFT on injury rates. As test attempts increased, injury risk decreased, after controlling for several relevant variables. This finding suggests that any elevation in injury risk may ultimately decrease to a lower plateau, although "cramming" for the ACFT or entry into the Army (which has a relatively quick ramp-up in physical activity and required administration of the ACFT for the first time) will likely guarantee a constant, though lower, level of risk. These temporal and practice factors suggest that continued monitoring (to ensure that the lower plateau of injuries occurs) and potential emphasis on scheduling the ACFT events near the beginning of the week may yield benefits.

Hicks and Robson (forthcoming) found that the SPT was not especially effective at capturing underlying physical fitness, particularly in the tails of the distribution. Instead, extraneous factors, such as height, had an effect on ACFT scoring. As we found in the current study, the SPT has another limitation when considering health and readiness goals: Soldiers who perform the best on the SPT are actually at *higher* injury risk in subsequent periods. As a result, it is unclear that SPT performance predicts medical readiness. Intended primarily to capture muscular power, the SPT measure may be swamped by irrelevant variance in the form of height. The Army may wish to consider alternatives that better meet the goals for this event or provide evidence that the SPT addresses other intended goals of the ACFT.

These findings and considerations lead us to our recommendations.

Recommendation: Include Additional Relevant Determinants of Injury Risk, Such as Demographic and Health Data, in Surveillance and Monitoring Systems

Demographic, occupational, and physical characteristics all provide useful information regarding injury risk. In spite of this, Army surveillance systems often either fail to include important related risk factors or fail to include them with the necessary timeliness, coverage, and frequency to permit rigorous insights from monitoring and surveillance. For instance, installation injury rates are tracked *over time*; however, other metrics—such as demographics for installations—are often provided only as current *snapshots*. To adequately assess injury risk, demographic profiles for installations, such as age and gender, and physical characteristics, such as body fat and BMI, should also be provided as a time series, as our study shows their clear association with injury rates. Being able to control for changing demographic, occupational, and physical influences on injury rates would enrich the analysis and monitoring of injury rates as a target for intervention.

Recommendation: Enhance Existing or Establish New Procedures to Collect Cause-of-Injury Data

Information relating to the cause of and setting for injuries is not consistently recorded in DHA health records. Although the immediate cause of injuries, such as cumulative microtrauma, may be difficult to determine, additional detail about the circumstances surrounding an injury, where available, would help determine whether particular types of physical training should be targets for intervention. Failed tests in which a soldier has to stop the event because of injury should record which event caused the injury.[24] These data are potentially of high value, and they can and should be collected alongside ACFT data at the time of the test to help develop data-driven ACFT policies.[25]

Recommendation: Incorporate Physical Fitness Assessments into Injury Surveillance

As documented in this report, the ACFT has substantial predictive power when assessing an individual soldier's current injury risk. Research literature reviewed by the study team suggests the same for the OPAT. Thus, we devote a recommendation to these data in particular. Injury

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[24] Tracking of injury and disability caused by ACFT testing could be facilitated by modification of DD Form 689, Individual Sick Slip, or DA Form 3349, Physical Profile. Checkboxes under the "mechanism of injury" section or other standardized methods may facilitate rapid annotation of which ACFT event provoked the injury. Over time, such tracking could facilitate data-driven policy decisions to add, drop, or modify test events or to update physical training guidance. For extensive discussion of injury surveillance opportunities related to the ACFT, see Avriette et al., forthcoming.

[25] A system such as DTMS may be able to collect additional information about testing conditions (such as temperature and humidity, altitude, and indoors or outdoors administration) and aggregate that information with outcomes, such as number of injuries or accidents. Tracking trends over time would help inform test administration policies and ensure that the ACFT retains its ability to represent a soldier's fitness fairly and comprehensively. For more discussion of data-driven ACFT policy development, see Avriette et al., forthcoming.

surveillance systems, whether aggregated or for individuals, could include information on fitness performance—both overall ACFT and individual event scores—as an additional early warning sign for risk. Ideally, this information could be included in medical records, but if that is not possible, the Army's own health surveillance systems could incorporate the information. Even when aggregated at the installation level, injury risk could be teased out—for example, by including the percentage of an installation in specific performance categories (such as the percentage of soldiers at an installation failing the ACFT).

Recommendation: Monitor ACFT Performance Throughout the Performance Range; Do Not Focus Only on Those Who Do Not Pass

The Army should recognize that the relationship between fitness performance and injury risk is nuanced. Looking across events, we found that injury risk is substantially higher for soldiers who fail any component of the ACFT. Further, for five events, overuse injury risk declines with improved overall scoring performance. The exception is the SPT (for which injury rates in the subsequent six months were highest among male higher performers). Yet higher performance does not always mean lower risk. For example, the risk of acute trauma is actually higher among some of the highest-performing male and female soldiers on the MDL and male soldiers on the SDC. It is possible for acute injury rates to reflect not only underlying fitness but also behavioral factors—such as the injury risk associated with highly competitive individuals pushing their limits on the day of the test. So far, these increases in injury risk are small, but it would be useful to assess injury rates among high-performing groups for each event to ensure that the standards are not set in ways that incentivize excessive risk.

Recommendation: Continue to Monitor Injury Risk and Track Trends

Our analysis suggests that injury risk falls with experience taking the ACFT and that the overall injury risk associated with taking the ACFT during the periods we examined might not be reflected by the injury risk of the ACFT as fully implemented. On the other hand, as the stakes of the test change (i.e., as its use for administrative purposes is implemented), higher levels of performance may be further incentivized. Because there is some increase in injury risk at the highest levels of event performance, attempting to achieve the highest scores possible, especially without adequate preparation, may have its own risk. Some of the indicators of risk seen in the literature, such as training initiation, and intense periods of physical activity, such being in basic training, were observed as risk factors for injury in our data as well. Attention to risk of injury based on motivational factors is a target for intervention via individualized training programs.

Further, in our efforts to contextualize the ACFT rollout, we observed some differences in the body regions at risk for injury: We found a slightly larger share of injuries to the spine and back and a decreased share of injuries to lower extremities. This difference could easily be driven by a change in emphasis in physical training from running to resistance training. Given that the ACFT is intended to be a more holistic assessment of physical fitness and to drive changes in training, this finding is not necessarily cause for concern. However, changes in the overall injury profile do warrant awareness and are potential targets for intervention, whether by H2F exercise and injury professionals designing training programs or medical personnel treating soldiers.

Recommendation: Systematically Collect Data on Desired Outcomes from Investments Such as H2F

Prior research has established that factors such as nutrition and sleep can affect injury risk (see, e.g., Santos et al., 2023). As described in its operating concept, H2F includes interventions intended to directly instill a more robust culture of fitness and increase general physical activity levels, as well as optimize other domains in addition to physical fitness, such as sleep and nutrition (Center for Initial Military Training, 2020). These investments could have sizable returns through reduced injury if effective, not least through more-consistent implementation of appropriate training progression to minimize injury. To rigorously assess the impact of this multidimensional initiative on injury rates, the Army should collect detailed information on the timing and intensity of the rollout and the behavioral activities and health-related behaviors of soldiers—and then use this information to assess impact. We documented large variations across installations in injury rates (both unconditional and after accounting for other risk factors), although our analysis happened too early in the rollout to evaluate the success of the program. Given the large burden of injuries in the Army, this variation suggests that there is likely value in using evidence-based targeting of these resources to the locations in which they could have the largest impact and for assessing the size of their benefits relative to their cost.

Appendix A

Medical Event Records and ACFT Data

This appendix provides additional details on medical event records, ACFT records, and technical details on ACFT business rules and data practices.

Medical Event Records

The MHS delivers care to U.S. Department of Defense (DoD) beneficiaries through direct care, which is provided in MTFs, and private-sector care, which is delivered by civilian providers and is contracted and paid for by TRICARE. For our study, we focused on care delivered to active component service members. All administrative medical data files for inpatient and outpatient direct care and private-sector care are in the MDR, a data source maintained by DHA. We used medical files from the MDR to determine injuries sustained by service members based on only the primary diagnosis code. Table A.1 lists the data files used in our analyses.

Table A.1. Content of the Medical Encounter Files Used in the Analyses

Content	Data File
Outpatient services delivered at MTFs (direct care)	Comprehensive Ambulatory Professional Encounter Record (CAPER)
Inpatient services delivered at MTFs (direct care)	Standard Inpatient Data Record (SIDR)
Electronic health record outpatient data (direct care)	GENESIS Episodic Encounter
Electronic health record inpatient data (direct care)	GENESIS Admission
Provider services delivered outside MTFs (private-sector care)	TRICARE Encounter Data—Noninstitutional (TED-NI)
Facility services delivered outside MTFs (private-sector care)	TRICARE Encounter Data—Institutional (TED-I)
Inpatient and outpatient services delivered to deployed service members in theaters (direct care)	Theater Medical Data Store (TMDS)

Technical Details on ACFT Data

Period of Analysis

The Army provided RAND with more than two years of diagnostic ACFT performance records used in this study, spanning the period October 1, 2020, through March 31, 2023. For most analyses, we focused on the period of for-record tests in the active component spanning April 1, 2022, through October 1, 2022. For some analyses (e.g., producing an analysis of trends in BMI measured at the time of ACFT administration and studying changes in injury risk over subsequent test experiences), it was necessary to employ records from this full period. It is important to note the following limitations to analyses over the full period:

- Over this period, the scoring system and the composition of the test itself changed (first to add the PLK as an alternative to the LTK, then to alter plank testing, and then to remove the LTK, as well as changes to alternate event options).
- In addition, the Army's own data management and reporting practices changed such that the range of possible test scores on each event provided to RAND was not consistent over the sample period.
- On October 1, 2022, a large number of historical ACFTs were reconstituted for record while additional new tests were taken. There are reasons to believe that individuals who took the test on the first official day under which the test was for record might not be representative of all other test takers.

For these reasons, where possible, the majority of the analysis focused on the period spanning April 2022 to October 2022. This period most closely approximates the ACFT 3.0 status quo without moving so far forward in time that health records were unavailable in the DHA system, making this window of tests the most policy-relevant and actionable evidence we have to date. In addition, we note the following:

- During this period, all observed tests fell under the same (and current) age- and gender-normed scales, which became effective on April 1, 2022.
- During this period, there was a consistent approach to the reporting of individuals on profile in our data, with the majority of individuals who did not take an event being flagged in the data as such. (In previous data iterations, individuals were simply reported as having raw performances of zero push-ups or zero meters thrown on the SPT, which now is observed very infrequently.)
- Data provided by the Army had one consistent set of boundary rules applied to raw scores, which we discuss in the context of our own business rules in the next subsection.
- Although the tests were diagnostic, soldiers were eligible to take tests for record during this entire period.

Constructed Variables

For some analyses, we constructed retrospective scoring values for historical data using the current ACFT 3.0 scoring tables. We checked our algorithm for constructing these scoring values by using current ACFT results, and we verified the points assigned by our approach by comparing the raw scores against the current points assigned in DTMS since April 1, 2022.

We incorporated analysis of both the CDC BMI and Army BMI binning using the formula weight (lb) / [height (in)]^2 × 703 (CDC, 2022a). We assigned categories as follows for the CDC BMI:

- if BMI is less than 18.5, underweight
- if BMI is 18.5 to <25, healthy
- if BMI is 25.0 to <30, overweight
- if BMI is 30.0 or higher, obesity.

We assigned categories as follows for the Army BMI:

- if BMI is less than 18.5, underweight
- if BMI is 18.5 to <25, healthy
- if BMI is 25.0 to <27.5, low overweight,
- if BMI is 27.5 to <30, high overweight
- if BMI is 30.0 or higher, obesity.

Business Rules

We followed a set of common business rules when cleaning ACFT data records and excluded a small handful of records with no gender marker in DTMS. We also excluded a small sample of test results with scoring outcomes outside the expected range for the event. Otherwise, for most of the data provided by the Army since April 1, 2022, some business rules were generally applied. We followed those rules where possible, with minor exceptions, detailed as follows:

1. For the MDL, we included tests with scores in the range of 60 to 420. In the sample, 0.5 percent of tests included an MDL score below 60. Many of these scores were weight values that are not possible given the equipment. A small fraction had a score of 0. However, for some of the data period, there was a flag for "event MDL not taken," as well as zeros in the data; for other periods, there was no flag but higher numbers of zeros. As a result, MDL lift values of 0 were excluded. Inclusion of zeros would decrease MDL pass rates, but these zeros compose less than 0.5 percent of the sample, so the impact of their exclusion is not large.
2. For the SPT, we included only tests in the range of 1 meter to 19 meters. There was a small number of SPT values of 0, but we faced the same dilemma with a flag existing in only the most-recent data. Less than 0.2 percent of tests were excluded. We also excluded four tests with implausibly high test scores.
3. For the HRP, we followed the same approach as the MDL and the SPT, taking a range of 1 to 75. This excluded four observations above 75 (there was a large mass of tests at 75, suggesting that the Army might have been top coding tests at this value for most tests). We excluded 0.3 percent of tests by removing tests results showing zero pushups.
4. For the PLK, we excluded two values above 330 seconds. There were clumps of scores at 330 seconds.
5. For the 2MR, we allowed the score range of 480 to 2,400 seconds. This range excluded one test with a run time of 0 and 44 tests with excessive run times not allowed by the ACFT guidance.

Appendix B

Technical Details of the Empirical Analysis

This appendix provides technical details about the empirical approaches used throughout the report. The appendix presents an overview of the survival analysis methodology and a discussion of the trade-offs in the predictive analysis of using raw performance data as opposed to using the ACFT data after applying the scoring system.

Survival Analysis

An analysis of the association between physical fitness assessments and injuries lends itself to survival analysis for several reasons. We are inherently interested in the risk that an injury occurs over a given period. This could be the time during training, the time leading up to a test for which an individual might seek a profile designation, the day of the test, a short window after the test in which an individual might seek treatment for an injury sustained while taking the test, and the period in which physical assessments are not looming. Although we did not produce survival or failure curves, we recognize that there is valuable information in the time between an event and the timing of injury. Using survival analysis helped us leverage this variation in the data.

Moreover, our primary focus is on identifying the factors that affect the time to an initial injury. Once a soldier suffers an injury, they exit the analysis. Subsequent encounters could be follow-up visits or injury relapses, and including multiple visits for a soldier would otherwise overstate estimated potential injury risk. This approach also lessens the possibility of reverse causality, in which injuries lead to poorer physical fitness performance and thus poorer performance looking as if it increases injuries when the root cause is an initial injury.

We employed the Cox proportional hazards model, a semiparametric regression analysis. Cox regression models are useful for providing an estimate of the relative risk of an outcome across a set of groups. In fact, the model does not require the baseline hazard function $h_O(t)$—in this case the risk of an injury or a specific type of injury—to even be specified. Instead, the key assumption is that covariates multiplicatively shift the baseline hazard. In other words, Cox proportional hazard models do not answer the question of how much risk of an injury a soldier faces at an exact moment in time. Instead, the models answer the question of how much more risk a soldier who is 42 years old faces than one who is 24. We employed several Cox proportional hazard models, and each regression took the following general form:

$$h(t|\mathrm{X_K}) = h_O(t)e^{(B_1x_1+B_2x_2+\cdots+B_kx_k)},$$

where, $h(t)$ is the hazard rate, t indexes analysis time, and X_K is a vector of covariates (some may be of interest and others may simply serve as controls). Although it is possible for a baseline hazard to be estimated, we used logistic regressions for those analyses for simplicity and let the regression coefficients on the survival model covariates, denoted by B_k, be the primary focus of the following analysis.

Table B.1 presents our preliminary specification for the association between ACFT performance and injury risk as a function of DTMS scoring performance, as in Table 4.3. In addition to the primary X_K of interest, DTMS performance, we include coefficients on control variables from the regression. As shown in Table B.1, although the magnitudes have changed, the sign and general impact of many control variables are broadly similar to those estimates from the univariate analysis presented in Chapter 4.

Table B.1. The Association Between the ACFT and Subsequent MSKI Risk by Injury Type (with Additional Controls Depicted)

	All Injuries		Overuse Injuries		Acute Trauma Injuries	
Characteristic	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
ACFT scores 420–479	0.942***	0.938***	0.932***	0.939**	0.993	0.998
	(0.011)	(0.022)	(0.011)	(0.024)	(0.020)	(0.044)
ACFT scores 480–539	0.929***	0.913***	0.916***	0.901***	1.032	1.029
	(0.011)	(0.024)	(0.011)	(0.025)	(0.022)	(0.049)
ACFT scores 540–600	0.926***	0.872***	0.899***	0.865***	1.093***	1.002
	(0.012)	(0.030)	(0.013)	(0.032)	(0.026)	(0.063)
ACFT fail	1.230***	1.192***	1.254***	1.233***	1.170***	1.139***
	(0.017)	(0.032)	(0.019)	(0.034)	(0.029)	(0.055)
Obese	1.234***	1.155***	1.270***	1.145***	1.146***	1.274***
	(0.014)	(0.040)	(0.015)	(0.041)	(0.022)	(0.078)
Overweight	1.114***	1.098***	1.140***	1.101***	1.072***	1.076**
	(0.010)	(0.020)	(0.011)	(0.021)	(0.017)	(0.036)
Underweight	0.993	0.838*	0.927	0.834	0.980	0.954
	(0.070)	(0.086)	(0.073)	(0.092)	(0.120)	(0.175)
Ages 22–26	1.047***	0.917***	1.080***	0.932***	0.966*	0.829***
	(0.011)	(0.021)	(0.013)	(0.023)	(0.017)	(0.034)
Ages 27–31	1.103***	0.994	1.171***	1.038	0.950**	0.845***
	(0.013)	(0.026)	(0.015)	(0.028)	(0.019)	(0.039)
Ages 32–36	1.218***	1.031	1.337***	1.114***	0.945**	0.785***
	(0.016)	(0.031)	(0.019)	(0.035)	(0.022)	(0.044)
Ages 37–41	1.608***	1.244***	1.802***	1.340***	1.142***	0.836***
	(0.023)	(0.043)	(0.028)	(0.049)	(0.030)	(0.056)
Ages 42–46	1.930***	1.445***	2.219***	1.562***	1.174***	0.976
	(0.037)	(0.068)	(0.044)	(0.077)	(0.042)	(0.087)

Characteristic	All Injuries		Overuse Injuries		Acute Trauma Injuries	
	Male	Female	Male	Female	Male	Female
Ages 47–51	2.211***	1.508***	2.527***	1.689***	1.323***	1.048
	(0.059)	(0.101)	(0.070)	(0.115)	(0.067)	(0.136)
Ages 52–56	2.168***	1.907***	2.391***	2.046***	1.424***	1.237
	(0.098)	(0.186)	(0.113)	(0.207)	(0.119)	(0.238)
Ages 57–61	2.949***	2.054***	3.273***	2.297***	2.337***	0.667
	(0.309)	(0.480)	(0.354)	(0.532)	(0.411)	(0.394)
Age 62+	2.803**		3.510**			
	(1.454)		(1.837)			
Enlisted	1.308***	1.330***	1.308***	1.352***	1.305***	1.279***
	(0.015)	(0.031)	(0.016)	(0.033)	(0.027)	(0.056)
Warrant officer	1.064***	1.111	1.079***	1.130*	0.992	1.160
	(0.025)	(0.075)	(0.026)	(0.078)	(0.045)	(0.147)
Profile flag in DTMS	1.286***	1.300***	1.316***	1.354***	1.122***	1.099
	(0.022)	(0.040)	(0.023)	(0.043)	(0.036)	(0.063)
Month-of-test indicators	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-week indicators	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	281,444	44,404	283,022	44,693	292,480	47,193

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The data are from ACFTs taken between April 2022 and October 2022. We conducted a survival analysis using the Cox proportional hazard model. Robust standard errors are in parentheses. The reference age category is 17–21, and the reference BMI group is normal. The analysis window spans eight days through 180 days following the test.
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Raw Event Performance Versus ACFT Scoring System Application

In this section, we present results from the analysis of raw event performances (i.e., pounds lifted on the MDL, meters thrown for the SPT, number of push-ups for the HRP, and seconds for the SDC, the PLK, and the 2MR). All estimates are for better performance; therefore, to allow for event comparability, the SDC, the PLK, and the 2MR are reversed such that the coefficient interpretation is for *fewer* seconds. All event performances have been transformed as the natural log so that the interpretation is, for a 10 percent improvement in each event, the hazard rate of injury shifts by X percent (of the coefficient presented).

These estimates in Table B.2 and Table B.3 are presented for comparability with preexisting literature and because the main results presented in the report are based on the contemporaneous scoring system selected by the Army. The ACFT scoring system has already been changed and may continue to evolve. These results provide estimates that will remain relevant for targeting injury risk even if the scoring system changes further. Results for each event are presented individually for each event and then jointly. Estimates for male and female soldiers are presented separately, and the set of controls employed in the report analysis are also included.

Table B.2. Raw Event Performances for Male Soldiers

	MDL	SPT	HRP	SDC	PLK	2MR	All
Panel A: Dependent Variable: Any Injury							
LN(MDL)	0.92***						0.97
	(0.01)						(0.02)
LN(SPT)		1.07***					1.27***
		(0.02)					(0.03)
LN(HRP)			0.92***				0.97**
			(0.01)				(0.01)
LN(SDC)				0.79***			0.94
				(0.02)			(0.04)
LN(PLK)					1.11***		0.98
					(0.01)		(0.01)
LN(2MR)						0.58***	0.59***
						(0.02)	(0.02)
Panel B: Dependent Variable: Overuse Injury							
LN(MDL)	0.89***						0.95**
	(0.01)						(0.02)
LN(SPT)		1.03					1.27***
		(0.02)					(0.04)
LN(HRP)			0.92***				1.00
			(0.01)				(0.01)
LN(SDC)				0.72***			0.89***
				(0.02)			(0.04)
LN(PLK)					1.13***		0.99
					(0.01)		(0.02)
LN(2MR)						0.53***	0.54***
						(0.01)	(0.02)
Panel C: Dependent Variable: Acute Trauma Injury							
LN(MDL)	1.09***						1.07**
	(0.03)						(0.04)
LN(SPT)		1.40					1.41***
		(0.06)					(0.07)
LN(HRP)			0.97***				0.91
			(0.01)				(0.02)
LN(SDC)				1.19***			1.21***
				(0.06)			(0.08)
LN(PLK)					1.02***		0.97

	MDL	SPT	HRP	SDC	PLK	2MR	All
					(0.02)		(0.03)
LN(2MR)						0.80***	0.70***
						(0.04)	(0.04)
Profile flag	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rank category	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physical characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Demographic controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month-of-test indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-week indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	234,727	235,000	234,637	234,470	235,123	227,260	226,580

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.

NOTE: The SDC, the PLK, and the 2MR (the timed events) are included as negative values to keep the interpretation of results the same for all six events (the impact of better performance on injury hazards). The data are from ACFTs taken between April 2022 and October 2022. We conducted a survival analysis using the Cox proportional hazard model. Robust standard errors are in parentheses. We include a control for permanent-profile status, indicators for rank category (i.e., officer, enlisted, warrant officer), BMI category, ACFT age group, month of test, and day of the week of test. The analysis window spans eight days through 180 days following the test. LN = natural log. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Table B.3. Raw Event Performances for Female Soldiers

	MDL	SPT	HRP	SDC	PLK	2MR	All
Panel A: Dependent Variable: Any Injury							
LN(MDL)	0.94*						1.19***
	(0.04)						(0.07)
LN(SPT)		0.93*					1.01
		(0.04)					(0.05)
LN(HRP)			0.92***				0.98
			(0.02)				(0.02)
LN(SDC)				0.68***			0.84**
				(0.04)			(0.06)
LN(PLK)					1.17***		1.02
					(0.03)		(0.04)
LN(2MR)						0.52***	0.54***
						(0.03)	(0.04)
Panel B: Dependent Variable: Overuse Injury							
LN(MDL)				0.91**			1.16**
	(0.04)						(0.07)
LN(SPT)		0.93*					1.05
		(0.04)					(0.06)
LN(HRP)			0.91***				0.97
			(0.02)				(0.03)
LN(SDC)				0.64***			0.79***
				(0.04)			(0.06)
LN(PLK)					1.19***		1.02
					(0.03)		(0.04)
LN(2MR)						0.48***	0.52***
						(0.03)	(0.04)
Panel C: Dependent Variable: Acute Trauma Injury							
LN(MDL)				1.13**			1.29**
	(0.09)						(0.14)
LN(SPT)		1.06*					1.04
		(0.08)					(0.10)
LN(HRP)			0.97***				0.98
			(0.03)				(0.04)
LN(SDC)				0.93***			0.97***
				(0.09)			(0.13)
LN(PLK)					1.10***		1.03
					(0.05)		(0.06)
LN(2MR)						0.71***	0.68***
						(0.08)	(0.09)
Profile flag	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	MDL	SPT	HRP	SDC	PLK	2MR	All
Rank category	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physical characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Demographic controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month-of-test indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-week indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	36,356	36,554	36,390	36,201	36,629	34,263	33,924

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The SDC, the PLK, and the 2MR (the timed events) are included as negative values to keep the interpretation of results the same for all six events (the impact of better performance on injury hazards). The data are from ACFTs taken between April 2022 and October 2022. We conducted a survival analysis using the Cox proportional hazard model. Robust standard errors are in parentheses. We include a control for permanent-profile status, indicators for rank category (i.e., officer, enlisted, warrant officer), BMI category, ACFT age group, month of test, and day of the week of test. The analysis window spans eight days through 180 days following the test. LN = natural log.
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Appendix C

Injury Classification

This report defines injuries using *A Taxonomy of Injuries for Public Health Monitoring and Reporting* developed by the Injury Prevention Branch of the Defense Centers for Public Health—Aberdeen (formerly APHC). Specifically, we started with the master injury taxonomy spreadsheet ("2023 TAXONOMY_w Body Region_APHC_IPD_INJURY CODES.xlsx") referenced in Hauschild et al. (2021) and made available to us by the Injury Prevention Branch. This file contains all ICD-10-CM diagnosis codes used after October 1, 2015. We cleaned and subsetted the taxonomy as follows.

First, we cleaned and deduplicated records to create a file unique at the level of the ICD-10-CM diagnosis code (74,296 unique codes) by

- removing leading and trailing spaces from ICD-10-CM code and definition fields, energy category fields, body region fields, and injury type fields
- standardizing string fields to a single letter-case type (uppercase)
- dropping records with exact-duplicate ICD-10-CM code and definition fields, energy category fields, body region fields, and injury type fields (216 exact-duplicate records)
- reviewing duplicate ICD-10-CM code records with slight variations on the string ICD-10-CM definition field and retaining the shortest definition string for reference (19 duplicate records)
- retaining records with injury taxonomy information for the remaining duplicate ICD-10-CM code records (single ICD-10-CM code, "U07.0 Vaping-related disorder," is listed with and without injury taxonomy).

Second, we reviewed the fields for general body region and specific body region for consistency. We revised the general body region (from lower extremity to upper extremity) for the following shoulder and elbow ICD-10-CM diagnosis codes:

- "M97.32XA Periprosthetic fracture around internal prosthetic left shoulder joint, initial encounter"
- "M97.41XA Periprosthetic fracture around internal prosthetic right elbow joint, initial encounter"
- "M97.42XA Periprosthetic fracture around internal prosthetic left elbow joint, initial encounter."

Third, we restricted to ICD-10-CM diagnosis codes classified in the taxonomy as mechanical energy injuries, because nonmechanical energy injuries (environmental, nonenvironmental, poisonings), other and unspecified injuries, and noninjury diagnoses are not the focus of this study. This restriction discards 64,426 ICD-10-CM diagnosis codes, leaving 9,870 unique ICD-10-CM codes (Table C.1). Finally, we retained the mechanical energy category, general body region, and injury type (e.g., dislocation, fracture, strain or tear) for all 9,870 ICD-10-CM codes, as well as the specific body region for upper-extremity and lower-extremity injury codes. The application of the taxonomy to DHA health data is described in Appendix A.

Table C.1. Categories for Mechanical Energy and General Body Region

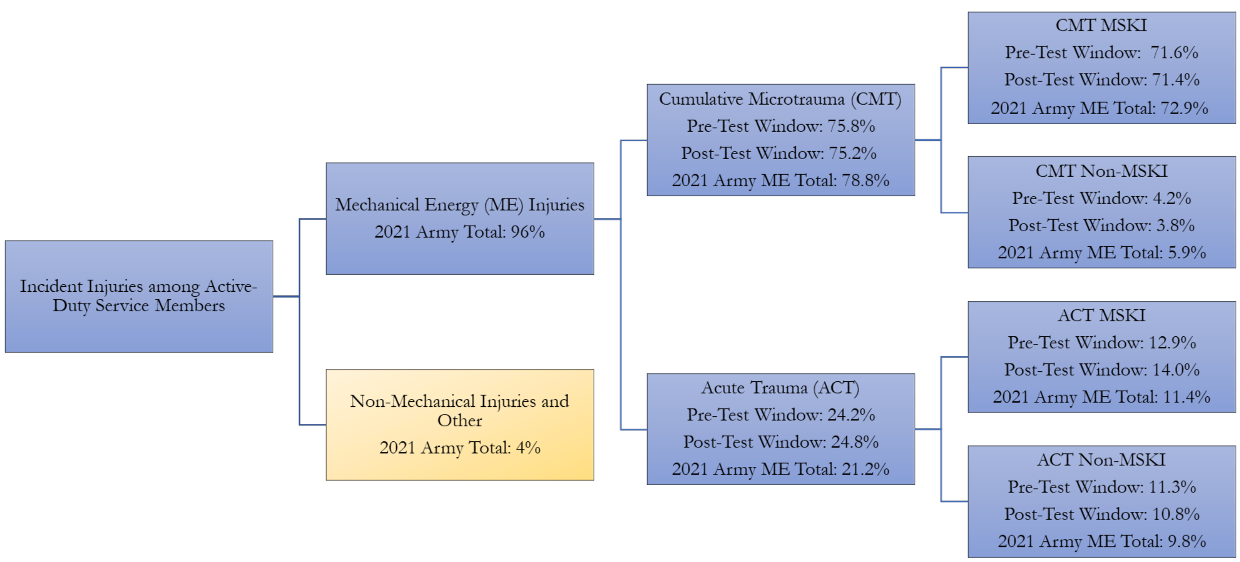
Mechanical Energy Category	General Body Region	Number of ICD-10-CM Diagnosis Codes
Acute trauma MSK	Head and neck	183
Acute trauma MSK	Lower extremity	2,355
Acute trauma MSK	Other	26
Acute trauma MSK	Spine and back	415
Acute trauma MSK	Torso	266
Acute trauma MSK	Upper extremity	2,689
Acute trauma non-MSK	Head and neck	812
Acute trauma non-MSK	Lower extremity	644
Acute trauma non-MSK	Other	3
Acute trauma non-MSK	Spine and back	113
Acute trauma non-MSK	Torso	835
Acute trauma non-MSK	Upper extremity	804
Cumulative microtrauma MSK	Head and neck	2
Cumulative microtrauma MSK	Lower extremity	217
Cumulative microtrauma MSK	Other	45
Cumulative microtrauma MSK	Spine and back	84
Cumulative microtrauma MSK	Torso	2
Cumulative microtrauma MSK	Upper extremity	226
Cumulative microtrauma non-MSK	Head and neck	30
Cumulative microtrauma non-MSK	Lower extremity	40
Cumulative microtrauma non-MSK	Other	2
Cumulative microtrauma non-MSK	Spine and back	13
Cumulative microtrauma non-MSK	Torso	21
Cumulative microtrauma non-MSK	Upper extremity	43
Total		9,870

SOURCE: RAND analysis of the Taxonomy of Injuries for Public Health Monitoring and Reporting developed by the Injury Prevention Branch of the Defense Centers for Public Health—Aberdeen (Hauschild et al., 2021).

Because we are interested in the relationship between the ACFT and injuries, our analysis window focuses on injuries sustained for individual soldiers in time windows around the ACFT. Active component soldiers are expected to take the ACFT two times per year, so we focused on the 180-day window preceding the ACFT date (pretest) and the 180-day window including and following the ACFT date (posttest). To better understand the profile of injuries we observed, we compared the composition of injuries in the pretest and posttest windows (across every ACFT record in our data) with those observed in calendar year 2021 from the *Annual Injury Surveillance Report 2021 Summary* published by the U.S. Army Public Health Center for the active component, which focuses on an annual window rather than windows around ACFT administration (Mahlmann, Schuh-Renner, and Canham-Chervak, 2023). Despite the difference in timing focus, this approach provided a check on the representativeness and reliability of the data we are working with.

As shown in Figure C.1, acute mechanical energy injuries are approximately evenly split between MSK (14.0 percent in the posttest window) and non-MSK (10.8 percent in the posttest window). Cumulative microtrauma (overuse injuries) are predominantly MSK (71.4 percent in the posttest window) in nature. This finding primarily reflects the injury risk to MSK systems posed by repetitive mechanical stress, such as training muscle groups. The proportions shown in Figure C.1 suggest that injury types observed in our analysis windows are not substantially different from those over the course of calendar year 2021.

Figure C.1. The Composition of Injuries by Characteristic and Outcome Under the APHC Injury Taxonomy



SOURCES: Injury data for calendar year 2021 are from Mahlmann, Schuh-Renner, and Canham-Chervak, 2023. Pretest and posttest ACFT values are our calculations from ACFT dates and injury records provided to RAND over the period October 2020 to October 2022.

Apart from the differences between ACFT-bound and calendar year 2021 injury ratios, in which there are small differences in the pre- and posttest ratios, these ratios may give insight to policymakers on the divergence in injury risk during training and the lead-up to an ACFT (pretest) as opposed to the injury risk faced by taking the test and in the window of time after the test (posttest). For instance, overuse injuries are more frequent in the period before the test (perhaps reflecting training or characterizations of medical profile for nagging injuries), and acute trauma injuries are proportionately more frequent when looking at the test day and days that follow (perhaps reflecting risk of the test administration itself).[26]

[26] Total injuries are slightly more frequent in the post-ACFT period likely because of injuries sustained during the test and reported on, or shortly after, the test date.

Appendix D

Installation Injury Rates

This appendix presents preliminary evidence on injury risk across Army installations. Although the Health of the Force online (DHA—Public Health, 2022) and APHC provide estimates of injury rates per soldier per quarter at Army installations, many factors vary significantly across installations, including whether the site hosts basic combat training or advanced individual training, whether H2F and similar investments have been undertaken, and which demographic and physiological groups of soldiers are stationed there. As a first pass, we followed the primary analysis specifications in Chapter 3 and employed survival analysis to examine injury risk at the installation level. These results are presented in the "All Soldiers" column of Table D.1.

Unlike unconditional injury rates, these estimates present the hazard of injury for soldiers in comparison with Fort Liberty, after controlling for factors such as gender, BMI, rank category, and age. Fort Liberty, North Carolina, was chosen as the baseline comparator because it had the largest sample of tests. We also present the unconditional injury incidence per 1,000 soldiers, drawn from existing surveillance systems, in the last column. The "2022 Injury Rate Relative to Fort Liberty" column presents the expected unadjusted injury rate relative to Fort Liberty. Taking the example of Fort Gordon, Georgia, we would expect to see a lower injury rate at that location after controlling for relevant demographics. However, Fort Gordon's injury rate is higher than Fort Liberty's. Thus, Fort Gordon would be a potential location to target injury interventions.

As can be seen from Table D.1, conditional and unconditional injury measures sometimes agree but not always. For example, Fort Leonard Wood, Missouri, had an injury rate in 2022 that was approximately 30 percent higher than that of Fort Liberty. At the same time, once the analysis is conditioned for demographics, such as age, we find that hazard rates for injury are similar to those for Fort Liberty given the installation profile.

Table D.1. Conditional Installation Hazard Rates and Unconditional Injury Rates

Army Location	All Soldiers	2022 Injury Rate Relative to Fort Liberty	2022 Injury Incidence per 1,000 Soldiers
Fort Liberty	1 Ref	Ref	1,332.75
Korean Peninsula, Area IV	0.85*** (0.03)	87.84%	1,170.75
Korean Peninsula, Area II	0.98 (0.03)	90.56%	1,207.0
Korean Peninsula, Area III	0.98 (0.01)	100.56%	1,340.25
U.S. Army Garrison Bavaria	0.94*** (0.02)	97.96%	1,305.5
Fort Belvoir	1.04 (0.03)	141.92%	1,891.5
Fort Gordon	0.94*** (0.01)	120.80%	1,610.0
Fort Bliss	0.92*** (0.01)	99.44%	1,325.25
Fort Campbell	1 (0.01)	105.33%	1,403.75
Fort Carson	0.77*** (0.01)	77.32%	1,030.5
Fort Drum	1.03*** (0.01)	105.63%	1,407.75
Fort George G. Meade	0.95** (0.02)	128.76%	1,716.0
Fort Cavazos	0.96*** (0.01)	98.24%	1,309.25
Fort Huachuca	0.90*** (0.02)	104.20%	1,388.75
Fort Irwin	0.83*** (0.02)	103.15%	1,374.75
Fort Jackson	1.42*** (0.02)	137.10%	1,827.25
Fort Knox	1.21*** (0.03)	114.16%	1,521.5
Fort Leavenworth	0.95** (0.03)	118.74%	1,582.5
Fort Gregg-Adams	1.16*** (0.02)	112.53%	1,499.75
Fort Leonard Wood	1.02 (0.01)	130.07%	1,733.5
Joint Base Myer-Henderson Hall	0.93** (0.03)	103.53%	1,379.75

Army Location	All Soldiers	2022 Injury Rate Relative to Fort Liberty	2022 Injury Incidence per 1,000 Soldiers
Fort Johnson	0.87*** (0.01)	97.24%	1,296.0
Fort Riley	0.68*** (0.01)	70.94%	945.5
Fort Novosel	0.98 (0.03)	98.57%	1,313.75
Joint Base San Antonio	0.87*** (0.02)	106.13%	1,414.5
Fort Shafter	1.09*** (0.03)	100.11%	1,334.25
Fort Sill	1.04*** (0.01)	123.69%	1,648.5
Fort Stewart	1.00 (0.01)	92.07%	1,227.0
Fort Wainwright	0.91*** (0.02)	92.14%	1,228.0
Joint Base Elmendorf-Richardson	1.00 (0.02)	94.34%	1,257.25
Joint Base Langley-Eustis	1.28*** (0.03)	146.20%	1,948.5
Joint Base Lewis-McChord	0.81*** (0.01)	90.15%	1,201.5
Presidio of Monterey	0.80*** (0.03)	86.64%	1,154.75
Schofield Barracks	1.03** (0.01)	100.11%	1,334.25
U.S. Army Garrison Rheinland-Pfalz	1.08*** (0.03)	122.87%	1,637.5

SOURCE: Authors' calculations using ACFT data provided by the Army and injury data provided by DHA.
NOTE: The data are from ACFTs taken between October 2020 and October 2022 for Army locations with at least 3,000 tests in our data extracts. We conducted a survival analysis using the Cox proportional hazard model. Robust standard errors are in parentheses. We include a control for gender, permanent-profile status, indicators for rank category (i.e., officer, enlisted, warrant), BMI category, ACFT age group, month of test, and day of the week. The analysis window spans eight days through 180 days following the test. *Ref* = reference (the reference, or omitted, category for a categorical variable).
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Appendix E

Physical Fitness and Health Literature Review

In this appendix, we review the literature that has sought to establish predictive relationships between physical fitness assessment performance and subsequent injury. Although the exercise physiology literature is quite large, we focus here on research that uses an individual's physical performance to assess their probability of injury. These studies can help inform military decisionmakers about which physical fitness tests can most clearly identify soldiers at highest risk of injury.

This appendix describes the literature review methodology and presents a summary of findings. A discussion follows to illustrate the limits of physical fitness test events' predictive capacity of subsequent injury.[27]

Methodology

Three databases were queried with the search terms. EBSCO was included for broad subject matter within academic libraries and PubMed for high-quality scientific and medical articles. The Defense Technical Information Center (DTIC) is a database for military-funded scientific and technical content. Although DTIC requires a common access card to ensure the security of controlled information, all articles reviewed for this study were publicly available and did not have restricted distributions. A PICTOSS (population, intervention, comparator, timing, outcome, setting, study) formulation for search terms was used, generating the terms shown in Table E.1.

The population of interest was restricted to military, first responders, and similar physically demanding occupations. Elite athletes were excluded because of the different training intensity, available training resources, and motivations for success. Studies on pediatric or geriatric populations were excluded because of metabolic differences from military-age participants. Studies that focused on occupational physical fitness assessments had the most similarity to how the ACFT is used by Army senior leaders to ensure a minimum level of force fitness.

Initial search results included 67 PubMed articles, 16 EBSCO articles, and 28 DTIC articles. All were screened for military or military-like setting, administration of a physical fitness test prior to an injury-monitoring period, and whether the performance on the initial physical fitness test was

[27] In this discussion, the term *test* refers to a battery of testing events or a composite score generated from total performance across myriad component events. The term *event* is used to describe a single event, such as the 2MR, a component event of the APFT.

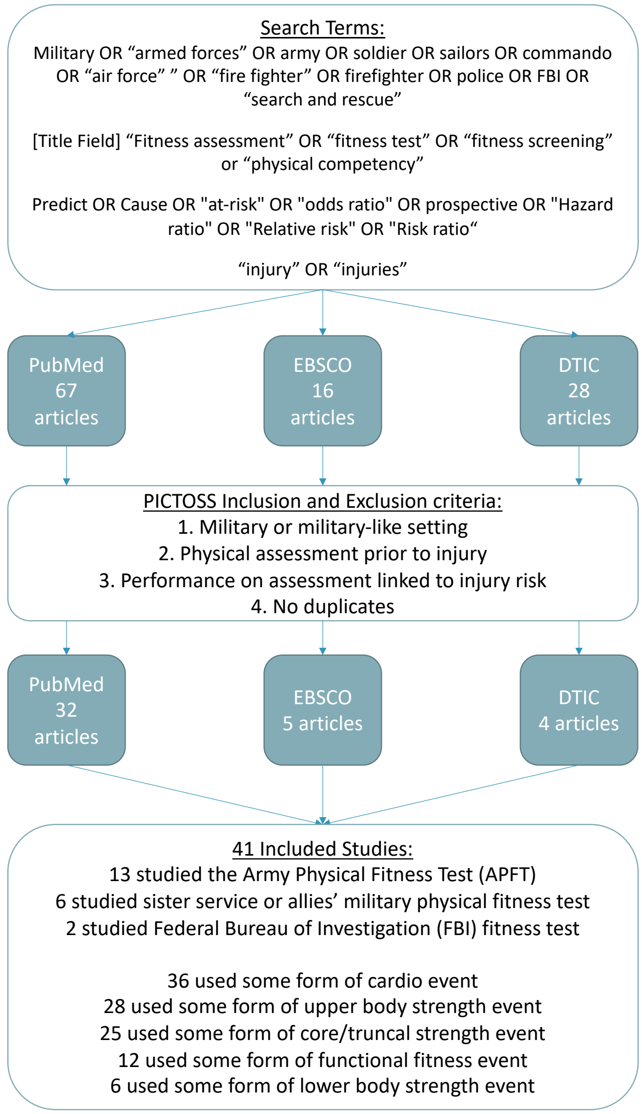
correlated with subsequent injury risk. Duplicates were removed. A flow chart depicting the screening process appears in Figure E.1. A total of 41 articles were included for full-text analysis.

Table E.1. Search Terms

PICTOSS	Search Terms	Exclusion Criteria
Population	Military OR "armed forces" OR army OR soldier OR sailors OR commando OR "air force" OR "fire fighter" OR firefighter OR police OR FBI OR "search and rescue"	Elite athletes, geriatric populations, pediatric (<18 years old)
Intervention	[Title field] "Fitness assessment" OR "fitness test" OR "fitness screening" or "physical competency"	Treatment, nutrition, and mental health studies
Comparator	Predict OR Cause OR "at-risk" OR "odds ratio" OR prospective OR "Hazard ratio" OR "Relative risk" OR "Risk ratio"	Performance on assessment must predict *subsequent* injury rates or types
Timing		If follow-up exceeds one year of assessment
Outcome	"injury" or "injuries"	
Setting		If study does not include military or military-style occupational training centers (military, fire, police, FBI, search and rescue)
Study		If not in English

NOTE: FBI = Federal Bureau of Investigation.

Figure E.1. Flow Chart of the Literature Review



Results

Of the 41 articles included in the analysis, 21 reported a predictive relationship between physical fitness tests and subsequent injury rates, although not all reviewed articles sought primarily to determine this relationship and instead focused on other outcomes, such as training program attrition. There was a broad variety of physical fitness tests and physical fitness events administered among the studies.

The most common physical fitness test battery was the APFT (13 studies), followed by other armed forces' fitness tests (six), and the FBI's fitness test (two). Other studies used unique combinations of events. Although most studies examined injury patterns for relationships with individual events, some reports correlated subsequent injury with composite test scores.

Cardiorespiratory events (36) were the most commonly included fitness event, followed by upper-body-strength and power events (28), core or truncal-strength and endurance events (25), and functional fitness events, such as standardized rucking or functional movement scoring (12). Finally, lower-body strength and power events (not including step-test events or running) were the least commonly included (six). Because most of the studies used more than one fitness event, the numbers do not sum to the total included studies.

The term *injury* applies to many types of medical events; in this review, we were most interested in MSKIs but did not restrict the search to only this term. Several studies reported injury without further descriptions (seven). Others used MSKIs with descriptors such as "lower limb," "overuse," or "acute/traumatic" (11). Several studies contained great granularity of injury types reported, including multiple injury types and International Classification of Diseases (ICD)–9 codes (12). Finally, a few studies were conducted to evaluate the effect on a single injury type, such as exertional heat injury or bone stress injury (three). A physical fitness event may hold predictive value for some injuries but not others; thus, results cannot be generalized.

In addition to what was recorded as an injury, there was considerable difference in measurement methods. Evans et al. (2005) used self-report surveys, and others (12) carefully cataloged medical diagnosis codes. As a result of measurement differences, self-report studies might have had higher apparent injury rates, whereas studies that required medical visits, testing, and diagnosis might have had lower apparent injury rates.

The conditions under which study participants were monitored for injury varied dramatically and might have contributed to injury rates. The monitoring period covered a variety of scenarios, from a year of unprogrammed fitness training (Evans et al., 2005), six months of participation in an extreme conditioning program (Grier et al., 2013), and a 12-week U.S. Marine Corps basic military training (Wallace et al., 2006). As a result, baseline MSKI risk cannot be generalized across studies because ongoing MSK training differences. The follow-up window during which participants were monitored for injuries also varied. For the 21 articles that established a predictive link between physical fitness assessments and subsequent injury risk, all monitored for injuries for a year or less. As a result of this variation, study results cannot be combined using meta-analysis methods to estimate absolute injury risk correlated with a physical fitness performance.

The underlying fitness of the participants varied, although all (41) selected studies took place in military or military-like settings. However, some studies examined military populations within the first few weeks of service entry; these individuals' fitness would be expected to be more similar to that of a civilian population than longer-serving military populations or special operations forces. Twenty-five studies tested recruits at reception into military (or federal) service, and 16 used in-service members (including cadets). The difference between these two populations' fitness is potentially large, and thus predictive relationships found in one population might not generalize to another. Two studies evaluated elite subpopulations within the military (such as Teyhen et al., 2015, which evaluated injury risks within an Army Ranger battalion). Not all studies reported baseline physical fitness parameters, making generalization of predictive patterns difficult. The heterogeneity of baseline fitness among military recruits increases the generalizability of results to nonmilitary settings but not necessarily to elite-athlete populations.

The studies did not distinguish between injuries caused by the assessment test and those recorded during the observation period.[28] As a result, a physical fitness event or test battery that had a higher rate of injury during the initial testing phase might have appeared to have higher injury rates. If the test disproportionately injured unfit individuals, it might have appeared to have higher predictive value of injury risk. In in Chapter 3, we provided evidence for injuries that were likely to have been sustained while taking the ACFT and the predictive value for tests beyond that window.

Our discussion differentiated between semiannual fitness tests and those that are administered once. Studies on the APFT and similarly periodically administered tests likely influence a military population to train to the test over their service years and thus are more likely to have lower injury rates associated with the test. Experimental test batteries do not allow for adaptation over time and thus may create a higher apparent injury rate from the novel test. If experimental fitness tests disproportionately injure unfit individuals, these one-off tests may appear to have higher injury predictive value.

Because of the wide variety of injury types, measurement methods, follow-up period and conditions, and other factors, we found the most useful method to discuss the predictive value of physical fitness testing events was to group them by test event type or by test battery. As a result, some studies will appear in more than one section, determined by the types of test events used. This allows the reader to ascertain the predictive value of each event type and understand negative results more clearly. To aid the reader in navigating the inherent complexity, a summary table is provided in each remaining subsection to outline the studies reviewed and each study's relevant findings.

We begin with military periodic physical fitness test studies. The subsections are grouped by test component event: cardiorespiratory, upper-body strength, core or truncal strength, functional fitness, and lower-body strength. Because of the unique nature of the ACFT and the plethora of studies on military periodic physical fitness tests more broadly, these composite tests' ability to predict subsequent injury are reviewed separately from component events. We then cover cardiorespiratory fitness events and strength and power events (upper-body strength, lower-body strength, core or truncal strength, and functional movement).

Periodic Military Physical Fitness Test Studies

This section discusses the value of periodic military physical fitness tests (PFTs) to predict subsequent injury risk. This section does not include reception-station physical assessments or other forms of one-time physical assessments, such as the OPAT, which matches a recruit's physical ability to a suitable occupation. Periodic tests allow a service member to adapt their physical fitness over long periods. One-time tests, including the OPAT and reception-station assessment tests, are taken without physical fitness adaptation to the test and thus may appear to have different relationships with injury rates; therefore, we discuss these tests along with studies of one-time-administered test events.

[28] The one exception is Evans et al., 2005, which assessed for injuries caused by the fitness test itself.

The APFT

Of the 13 included studies that used the APFT, eight studies examined the relationship between APFT scores and injury propensity, which are listed in Table E.2. The APFT consists of two minutes of push-ups and two minutes of sit-ups, followed by a two-mile run. Six of the eight studies were univariate analyses. This poses statistical concerns if the variables have high collinearity, as may happen if, for example, a good running score is highly correlated with high push-up and sit-up scores or with lower BMI. An additional concern for univariate analysis is that the true athletic performance-to-injury predictive relationship may be nonlinear. For example, multimodal distributions may occur if both the highest and lowest performers injure the most frequently.

In reviewing the eight studies that examined the relationship between APFT performance and subsequent injury risk, clear patterns emerged, consistent with other sports medicine literature. The 2MR was predictive of injury risk in seven of eight studies, the Sit-Up event in four, and the Push-Up event in three studies. These findings, collectively, were consistent with our literature review findings more broadly.

The 2MR was predictive of injury risk in seven of eight studies using the APFT to evaluate injury risk (Snoddy and Henderson, 1994; Knapik et al., 2001; Evans et al., 2005; Grier et al., 2013; Teyhen et al., 2015; Anderson et al., 2017; Grier et al., 2017). The consistency of this finding was substantial, regardless of participants' gender (Knapik et al., 2001), recruit or elite-unit membership (Snoddy and Henderson, 1994; Teyhen et al., 2015), injury type (Snoddy and Henderson, 1994; Grier et al., 2013), and injury-recording methodology (Anderson et al., 2017; Evans et al., 2005; Grier et al., 2017).

A study of 188 U.S. Army Rangers did not find a statistically significant univariate relationship between 2MR times and subsequent injury. Times for the 2MR were still identified as predictive risk-factor variables in a multivariate analysis in which soldiers with multiple risk factors exhibited higher injury rates. Presenting with three or more predictors increased injury risk by 360 percent compared with soldiers with zero risk factors (95 percent confidence interval [CI]: 2.2–9.6). However, the small sample size and homogenous elite nature of the study population may reduce the predictive value of component test events; injury risk between Army Rangers who run quite fast and slightly less fast might not differ substantially (Teyhen et al., 2015).

Table E.2. Summary of Studies Examining the Relationship Between Injury Propensity and APFT Scores

Author	Year	Analysis Type	Significant Predictor, $p \leq 0.05$ (p-Value)[a]	Nonsignificant Predictor, $p > 0.05$ (p-Value)[a]	Outcome Variable	Concluded Relationship
Snoddy and Henderson	1994	Univariate	• APFT: – Push-Up (0.009) – Sit-Up (0.034) – 2MR (0.000)	• BMI (0.07) • Age (0.39) • Weight (0.12) • Injury history (0.72)	Recorded medical visits; training completion	The results of all three APFT events were statistically correlated with the number of medical visits (illness and injury) and overall likelihood to complete training. No other intake variables correlated with medical visits.
Knapik et al.	2001	Univariate	• APFT: – Push-Up (0.02) – Sit-Up, male (0.03) – 2MR (0.04)	• APFT: – Sit-Up, female (0.14) • Age (0.07) • Height (0.22) • BMI (0.10)	Recorded injuries	Slower run times and fewer push-ups were injury risk factors for both men and women. Both men and women with lower peak VO_2 had an increased likelihood of injury.
Evans et al.	2005	Univariate	• APFT: – Overall score (0.001) – Push-Up (0.003) – Sit-Up, male (0.04) – 2MR (0.001)	• Age • Gender • Rank • Workouts per week	Self-reported injury survey	Lowest-quartile performers in overall APFT score were 2.3 times more likely to report an injury than were those in the upper three quartiles ($p = 0.001$). Bottom-quartile performers in the Push-Up, Sit-Up, and 2MR faced higher injury rates of 1.5, 1.4, and 1.6, respectively.
Grier et al.	2013	Univariate	• APFT: – 2MR • BMI	• APFT: – Push-Up – Sit-Up	Recorded injuries	Soldiers participating in extreme conditioning programs similar to CrossFit with slow run times and high BMI had higher injury risks.
Teyhen et al.	2015	Risk factor model	• APFT: – Sit-Up – 2MR • BMI	• APFT: – Push-Up	Recorded injuries	Decreased performance on the 2MR and two-minute Sit-Up event were associated with increased injury risk, among others.

Author	Year	Analysis Type	Significant Predictor, $p \leq 0.05$ (*p*-Value)[a]	Nonsignificant Predictor, $p > 0.05$ (*p*-Value)[a]	Outcome Variable	Concluded Relationship
Anderson et al.	2017	Univariate	• APFT – Sit-Up (0.01) – 2MR (0.01) • BMI > 23.4% (0.01)	• APFT: – Push-Up • Gender • MOS • Smoking	Self-reported injury survey	Soldiers with high scores in the Sit-Up and the 2MR were less likely to report an injury, as were those with lower BMI.
Roy et al.	2016	Univariate	• APFT: – Sit-Up	• APFT: – Push-Up – 2MR	Self-reported injury survey	Higher performance on the Sit-Up decreased injury risk for deployed women.
Grier et al.	2017	Multivariate	• APFT: – 2MR (0.01)	• APFT: – Push-Up – Sit-Up • Body fat	Recorded Injuries	Injury risk associated with low performance on the 2MR with men (odds ratio [OR] slow/fast = 1.51, 95 percent CL 1.18–1.94) and women (OR slow/fast = 2.38, 95 percent CI: 1.04–5.74).

[a] The *p*-values are reported when the original study reported *p*-values. Because of the large heterogeneity in study design, not all reports computed *p*-values, and not all reports that computed *p*-values computed them for all variables.

For example, Anderson et al.'s 2016 survey of 4,384 male and 363 female Army light infantry soldiers found that the 2MR event was a statistically significant predictor of injury, with those who ran slower than 15.7 minutes experiencing a 53 percent higher injury risk than those who ran faster than 14.1 minutes (OR [≥15.68/≤14.13 minutes] =1.53; 95 percent CI = 1.26–1.85).[29] Rangers run two miles in 13.4–13.9 minutes, on average (Teyhen, Shaffer, et al., 2016); the study showed this elite population to be composed of individuals who among the general-purpose force would be considered low injury risk.

Another study of fit individuals found no correlation between the 2MR and injury risk. Roy et al. (2016) observed injury risk among deployed women and found no predictive value for the APFT's running event performance. However, the authors noted that this was an unusually fit population of

[29] There is slight variation among studies' 2MR cutoff times, but the average Ranger time generally qualifies for all low-injury-risk groups. A 2017 study by Grier et al. of 3,264 soldiers found a statistically significant relationship between 2MR times and injury risk, with slow males facing a 51 percent higher risk of injury than fast males (OR slow/fast = 1.51; 95 percent CI: 1.18–1.94) and slow females facing a 134 percent higher risk of injury than fast females (OR slow/fast = 2.38; 95 percent CI: 1.04–5.74). A slow 2MR for men was >15.63 minutes, and a slow 2MR for women was >18.43 minutes. Grier et al.'s 2013 study on active duty general-purpose forces found that the 2MR event was a statistically significant predictor of injury during participation in a high-intensity interval training–based regimen, with those who ran slower than 15.5 minutes facing a 76 percent higher injury risk than those who ran faster than 13.5 minutes (OR [≥15.51 minutes/≤13.52 minutes] =1.76; 95 percent CI: 1.13–2.74). Similarly, soldiers who ran slower than 19:21 minutes were 1.6 times as likely to experience a time-loss injury than those who ran faster than the passing score of 15:40 (95 percent CI = 1.0–2.4; $p = 0.04$) (Knapik et al., 2001).

women, with a median APFT score of 270 (300 maximum score) and fewer than three women running two miles in more than 19 minutes.

APFT 2MR times were reliable in predicting injury risk but of limited value in high-fitness study populations. In the subsequent sections, additional studies using other PFTs also noted cardiorespiratory events to be predictive of injury risk: the Marine Corps PFT (two), the British Army PFT (two), the FBI PFT (two), and the Swiss Army PFT (one).

Similar to other studies, the correlation between sit-up performance and subsequent injury risk had mixed results, with four of the eight APFT studies that evaluated this relationship finding predictive value (Knapik et al., 2001; Snoddy and Henderson, 1994; Evans et al., 2005; Teyhen et al., 2015). The relationship between sit-up performance and injury risk was not as clear as that for running. Teyhen et al. (2015) again found multivariate relationships between sit-up performance and injury risk, while Snoddy and Henderson used a very broad definition of *injury*, which included illness. As a result, the relationship between performance and MSKI was obfuscated. Evans et al. surveyed 1,532 Army soldiers and found statistically significant relationships between bottom-quartile test takers and self-reported injury rates. Lowes-quartile performers in the Sit-Up event reported injuries at a rate that was 1.4 times higher ($\chi 2$ test, $p = 0.04$) than those in the upper three quartiles (Evans et al., 2005).

Similar to other studies, correlation between push-up performance and subsequent injury risk had mixed results, with three of the eight APFT studies that evaluated this relationship finding predictive value (Knapik et al., 2001; Snoddy and Henderson, 1994; Evans et al., 2005). The 2001 study by Knapik et al. of 756 male and 474 female Army Basic Combat Training soldiers found a statistically predictive relationship between APFT failures and injury risk—but only when the failures were dramatic. Soldiers who performed fewer than 31 push-ups were 1.8 times as likely to experience a time-loss injury than those who passed, performing 42 push-ups or more (95 percent CI = 1.2–2.8; $p = 0.01$). Similarly, Evans et al. (2005) found injury-predictive relationships among substantially underperforming participants on the Push-Up; bottom-quartile performers reported injury at a rate that was 1.5 times higher than other participants. Other studies, reviewed below, that examined relationships between upper-body strength and injury risk were similarly equivocal.

U.S. Marine Corps PFT

One included study—Lisman et al. (2013)—used the Marine Corps' PFT. Findings regarding physical performance as an injury predictor were consistent with other periodic military standardized tests and other reviewed literature. One more study—Wallace et al. (2006)—used a modified format of the Marine Corps' PFT and assessed physical performance as a predictor for exertional heat illness (a form of heat stroke) among recruits.

A study by Lisman et al. (2013) of 874 male Marine Officer Candidates found a statistically significant relationship between three-mile run times and injury risk. Marines who ran slower than 20.5 minutes faced 1.7 times the injury risk of Marines with a run time faster than 20.5 minutes (95 percent confidence interval = 1.29–2.31; $p < 0.001$). As part of a multivariate analysis, officer candidates also took a functional movement screen (FMS). Candidates with both slow three-mile run times and FMS scores below 14 on a 21-point scale faced 4.2 times the injury risk of counterparts with faster three-mile run times and higher FMS scores (95 percent CI = 2.33–7.53; $p < 0.001$). The pull-up and abdominal crunch components of the U.S. Marine Corps PFT were not predictive of injury risk at a statistically significant level.

Wallace et al. (2006) used a modified Marine Corps PFT, consisting of pull-ups, sit-ups, and a 1.5-mile timed run administered to recruits during a 12-week course of basic military training. Using conditional logistic regression, the authors found that slower run times strongly predicted risk for exertional heat illness (EHI). The authors also found that BMI was predictive of a 9 percent increase in EHI risk among male recruits but not female recruits.

Table E.3. Summary of Studies Using the U.S. Marine Corps PFT

Author	Year	Analysis Type	Significant Predictor, $p \leq 0.05$ (p-Value)[a]	Nonsignificant Predictor, $p > 0.05$ (p-Value)[a]	Outcome Variable	Concluded Relationship
Lisman et al.	2013	Univariate	• Three-mile run (0.001) • FMS	• Pull-ups • Crunches	Medical records	The three-mile-run cardiorespiratory event was the only component of the Marine Corps PFT able to predict injury rates. Low FMS scores, combined with slow run times, also predicted injury.
Wallace et al.	2006	Multivariate	• 1.5-mile run (modification) • Race • BMI, male	• BMI, female	EHI	In men, BMI, race, and longer PFT run time were significantly associated with elevated EHI risk. Among women, only the initial run time was significantly associated with EHI risk.

[a] The p-values are reported when the original study reported p-values. Because of large heterogeneity in study design, not all reports computed p-values, and not all reports that computed p-values computed them for all variables.

Other Test Batteries

Cardiorespiratory event performance on foreign military periodic tests was predictive of subsequent injury risk, similar to other PFTs. A study of 1,641 Royal Navy trainees found a relationship between run times and injury risk, with slower-running male and female trainees facing higher injury rates (Allsopp et al., 2003). A smaller study of 227 female British Army recruits also found a statistically significant relationship between 1.5-mile run times and injury risk ($p < 0.0005$). In this study, each ten-second increase in run time from the reference value was correlated with an 8.3 percent increase in injury propensity (Heller and Stammers, 2020).

One study stood out for unusual conclusions. This study evaluated whether the Swiss Army PFT battery could identify Swiss Army recruits at elevated risk for acute and overuse injury (Wyss et al., 2012). The PFT consisted of a standing long jump, seated shot put, progressive endurance run, one-leg standing test, and a plank. The study was unable to draw relationships between PFT performance and subsequent acute injury risk. The authors found overuse injuries, on the other hand, to be correlated with truncal strength performance. Within three of four populations of recruits, a progressive endurance run was predictive. The splitting of the study population into multiple groups might have reduced statistical power. As shown below, nearly all studies that sought to correlate cardiorespiratory events with subsequent injuries found a strong predictive relationship. In contrast, the results from truncal strength tests are much more mixed.

Two studies evaluated the FBI PFT. Released in the same year by (mostly) the same authors (Knapik, Grier, et al., 2011; Knapik, Spiess, et al., 2011), both studies evaluated the predictors of injury among FBI recruits. The FBI PFT consists of push-ups, sit-ups, a 300-meter sprint, and a 1.5-mile run. In a six-year retrospective analysis of FBI PFT data, higher injury risk among men was associated with lower performance on push-ups, pull-ups, sit-ups, the 300-meter sprint, the 1.5-mile run, and total score. Among women, higher injury incidence was associated with lower performance on 1.5-mile run and the total score; weaker associations were shown between injuries and push-ups, sit-ups, and 300-meter-sprint performance. Following the retrospective study, a one-year prospective study of PFT performance found, among men, higher injury risk was associated with older age, slower 300-meter-sprint times, slower 1.5-mile-run times, and lower total points on the PFT (Knapik, Spiess, et al., 2011). Among the women, higher injury risk was associated with slower 300-meter-sprint times, slower 1.5-mile-run times, and lower total points on the PFT. In the discussion of this variability of outcomes, the authors mentioned that, during the retrospective study years, the FBI health clinic was intermittently staffed by a physician; thus, many diagnoses were made by nurses. During the one-year prospective study, the clinic was staffed by a full-time physician, bringing higher diagnostic specificity to injured participants. The shorter study also sought relationships between additional risk factors, which might have clarified variable relationships and interdependencies.

Cardiorespiratory Fitness Event Studies

Thirty-six studies in our review included a cardiorespiratory fitness event; 21 of these sought a relationship between cardiorespiratory performance and subsequent injury risk. *All but one of the 21 studies (95 percent) found a predictive relationship between cardiorespiratory performance and subsequent injury rates*. Of these, a large majority of the cardiorespiratory events that predicted subsequent injury were running events (18), and the remainder used step-test events, such as the Harvard step test (three). The duration of the running tests varied from 300 meters to three miles, and the duration of the step-test event was a uniform five minutes. Fourteen studies found a relationship between the cardiorespiratory event and military-style periodic PFTs, including the APFT (seven), Marine Corps PFT (two), British Army PFT (two), the FBI PFT (two), and the Swiss Army PFT (one); these results are discussed and tabulated in the previous section.

Six articles showed cardiorespiratory events' predictive value for injury risk, not otherwise covered above, which are summarized in Table E.4. Taken together, these studies indicate that slower run times or failures on step tests are associated with higher rates of EHI and MSKI, both acute and overuse. This effect was noted regardless of a participant's gender. Comparing the injury risk for poorer cardiorespiratory performance with stronger performance, we found that estimates of relative risk varied from 1.14 to 2.58, indicating a meaningful increase in injury risk associated with poor performance on cardiorespiratory events.

Table E.4. Summary of Studies of the Predictive Relationship of Injury and Cardiorespiratory Fitness Events

Author	Year	Cardiorespiratory Event Name	Injury Type	APFT or Military PFT?	Concluded Relationship
Knapik et al.	2004	One-mile run event	Any injury	1-1-1 test and others	The Reception Station PFT consisted of push-ups, sit-ups, and a one-mile run. Compared with individuals who passed the test, those who did not pass the test were 1.6 to 3.9 times more likely to get injured.
Sefton, Lohse, and McAdam	2016	One-mile run	MSKI, acute or overuse	1-1-1 test	One-mile-run time (1.6-km) predicted both overuse and acute MSKIs.
Bedno et al.	2014	Five-minute step test	EHI	No	Step-test failure was significantly associated with EHI.
Bedno et al.	2013	Harvard step test, modified	Overuse	No	The hazard rate ratio for injury among recruits who failed the fitness test compared with those who passed the test was 1.31 (95 percent CI: 1.20–1.44). The test was run at five-minute duration at 120 steps per minute on a 16-inch step.
Krauss et al.	2017	Five-minute step test	Multiple	No	Poor cardio fitness was associated with increased risk of MSKI, including stress fractures; the relative risk ratio was 1.32 (95 percent CI: 1.14–1.53).
Orr et al.	2020	20-m shuttle run, 2.4km run	Did not specify	Australian Army recruit PFT	A model was developed with fair predictive power, which associated higher BMI, female sex, older age, lower initial sit-up performance, and slower initial shuttle-run performance with higher risk for later injury.

NOTE: The 1-1-1 test is one minute of push-ups, one minute of sit-ups, and a one-mile run (see Sefton, Lohse, and McAdam, 2016).

Finding an increase in injury risk associated with poor performance on cardiorespiratory events is one of the most consistent findings of the literature review. Combining these six studies with the other 14 noted in the earlier "Periodic Military Physical Fitness Test Studies" section, cardiorespiratory event performance held particularly strong predictive value for subsequent injury, regardless of event duration. This finding is consistent with those in our main analysis: Low cardiorespiratory performers were at higher risk of injury.

Cardiorespiratory fitness may be linked to subsequent injury causally, although these observational studies are unable to prove a causal link. Individuals with lower levels of cardiorespiratory fitness must work harder to achieve similar physical performance in military training and thus may fatigue faster (Wyss et al., 2012). Biomechanics and proprioception may degrade as an individual fatigues, and thus abnormal forces on MSK structures may cause injury (Orr et al., 2021; Grier et al., 2017).

Some studies used a broader definition of *injury* and found a significant correlation between run-event performance and subsequent illness or injury, inclusive of upper respiratory infections (Snoddy and Henderson, 1994). At high levels of physical stress, the immune system is weakened (Devi et al., 2021); therefore, individuals entering the study with lower levels of aerobic fitness might have experienced higher levels of physical stress, making them more susceptible to contagious disease. As a result, the cardiorespiratory event performance of a recruit or active duty soldier may be predictive of subsequent illness risk.

The physiological principles required to achieve and maintain cardiorespiratory fitness present face validity as a protective factor for MSKI in a military population. The American College of Sports Medicine's guidelines to develop and maintain cardiorespiratory fitness are based on best evidence and recommend an otherwise healthy individual to perform either moderate aerobic activity for at least 30 minutes on five days per week or vigorous intensity aerobic activity for at least 20 minutes on three days per week (Garber et al., 2011). Depending on the individual's fitness prior to beginning an aerobic exercise program, it takes approximately five to 13 weeks to achieve or improve cardiorespiratory fitness (Montero, Diaz-Cañestro, and Lundby, 2015).

Interestingly, though, cardiorespiratory detraining—meaning a reduction in performance and fitness—can manifest in as little as one to two weeks after the cessation of aerobic activity (Slentz et al., 2007). An individual achieving and sustaining cardiorespiratory fitness requires consistency of training volume and progressive overload of the cardiorespiratory system. Because cardiorespiratory detraining occurs so quickly after cessation of exercise, the higher-performing individuals must have found a sustainable training volume, large enough to reap the benefits of ongoing training, and yet have not overtrained to the extent that they suffered injury—specifically, an injury that results in detraining.

Strength and Power Event Studies

Upper-Body Strength

Nineteen studies included in the review assessed an upper-body strength and power fitness event and injury risk. Results were mixed: Six studies found a predictive relationship between upper-body strength and power event performance and subsequent injury rates, and 13 did not. Of the studies using upper-body strength and power events, eight used the APFT, two used the USMC PFT, two used the FBI PFT, and five used other tests. Furthermore, three used a combination of data from other tests and the ACFT, and one used a combination of data from other tests and the USMC PFT. There was diversity of upper-body strength and power events used across studies, although push-ups (14) and pull-ups (two) were the most common, and two studies used both.

Results of the unmodified APFT and other U.S. military test batteries are covered above in the "Periodic Military Physical Fitness Test" section; all nine upper-body strength studies that do not solely use standard U.S. military fitness tests are outlined in Table E.5. Four tests—Grier et al. (2017), Teyhen et al. (2015), Knapik et al. (2011), and Wallace et al. (2006)—have mixed data sources and are listed on all relevant tables for completeness. *Of the nine upper-body strength studies included in this section, seven did not find predictive relationships between upper-body strength and power event performance and subsequent injury risk.* The two studies that found predictive value from upper-body strength and power events both had broad definitions of *injuries*, and one used a composite test score (Knapik et al., 2004) that incorporated other event scores—specifically, sit-ups and a run, the latter of which is independently predictive of injury risk.

Table E.5. Summary of Studies of the Predictive Relationship of Injury and Upper-Body Strength and Power Events

Author	Year	Upper-Body Strength and Power Event Name	Injury Type	APFT or Military PFT?	Concluded Relationship
Cowan et al.	2011	Push-ups	MSKI	No	The event required a minimum of 15 push-ups to be completed in one minute. No predictive association was found between push-ups and injury risk.
Knapik et al.	2004	One minute of push-ups	Any injury	1-1-1 test, and others	The Reception Station PFT consisted of push-ups, sit-ups, and a one-mile run. Compared with individuals who passed the test, those who did not pass the test were 1.6 to 3.9 times more likely to get injured.
Sefton, Lohse, and McAdam	2016	One minute of push-ups	Acute and overuse MSKI	1-1-1 test	No predictive association was found between push-ups and injury risk.
Orr et al.	2020	Two minutes of push-ups	Any injury	No	No predictive association was found between push-ups and injury risk.
Wallace et al.	2006	Flexed arm hang (women) or two minutes of pull-ups (men)	EHI	Marine Corps PFT (modified)	Initial PFT pull-ups were not significantly associated with risk for EHI.
Allsop et al.	2003	Press-ups (push-ups, including an alternative for women)	Any Injury	British PFT	No predictive association was found between push-ups and injury risk
Wyss et al.	2012	Seated shot put	Acute and overuse MSKI	Swiss Army PFT	The seated shot put did not have predictive value for acute or overuse injuries.
Grier et al.	2017	Two minutes of push-ups, pull-ups	Acute and overuse MSKI	APFT and others	No predictive association was found between push-ups, pull-ups, and injury risk.

Author	Year	Upper-Body Strength and Power Event Name	Injury Type	APFT or Military PFT?	Concluded Relationship
Knapik et al.	2001	Two minutes of push-ups, seated arm and shoulder pull, one-rep max	Multiple	APFT and others	Lower push-ups performance was an injury risk factor for both men and women. The seated arm and shoulder pull strength tests were not correlated with injury.
Teyhen et al.	2015	Two minutes of push-ups, upper-quadrant Y-balance test	Overuse MSKI	APFT and others	No predictive association was found between push-ups and injury risk.

Lower-Body Strength

Of the 41 included studies in the literature results, six studies included leg-strength tests, and only five studies included lower-body-strength events prior to evaluating injury risk.[30] The type of lower-body strength events varied substantially and included the dead lift, leg press, squat, unilateral knee extension, hip and knee flexor and extensor strength measured by a dynamometer, broad jump, and vertical jump. All studies used different leg-strength tests; there was no overlap except two studies using the long jump (Wyss et al., 2012; Grier et al., 2017). One study, a review article, found predictive value from declines in leg-strength performance to subsequent injury risk (Orr et al., 2021). Another study found equivocal results: Female intermediate-level performers were associated with higher injury rates than high- or low-level performers on a vertical-jump event (Grier et al., 2017); the study did not find this to be independent of other findings, however. The other five studies did not show a predictive link between lower-body strength and power event performance and subsequent injury risk. The results are summarized in Table E.6.

[30] One study correlated overall PFT score (including a dead lift event) with bone microarchitecture as a proxy for injury risk, but the relationship between bone microarchitecture and subsequent injury risk was not disambiguated (Wyss et al., 2012).

Table E.6. Summary of Studies of the Predictive Relationship of Injury and Lower-Body-Strength Events

Author	Year	Lower-Body Strength and Power Event Name	Injury Type	APFT or Military PFT?	Concluded Relationship
Orr et al.	2021	Leg press, squat, unilateral knee extension, leg strength, hip and knee flexor and extensor strength with dynamometer	Did not specify	OPAT and others	Study cited research that identified declines in vertical-jump height being linked to greater risk of both injury and illness in police personnel.
Wyss et al.	2012	Standing long jump	Acute and overuse MSKI	Swiss Army PFT	Standing long jump performance was equivocal for predicting subsequent injuries.
Grier et al.	2017	APFT (2MR), broad jump, vertical jump	Did not specify	APFT and others	Women with intermediate-level performance on the vertical jump were more likely than high performers or low performers to become injured (p = 0.03).
Knapik et al.	2001	Seated leg press and standing upright pull with legs and back, 1-rep maximums	Multiple	APFT and others	None of the strength tests was correlated with injury.
Knapik et al.	2004	Incremental dead lift	Any Injury	1-1-1 test and others	Performance on the incremental dead lift was not shown to be associated with injury risk.

The current analysis found insufficient evidence to support the use of lower-extremity strength and power event performance to predict future injury risk. When pairing the findings of the upper- and lower-body-strength and power event performance literature, strength testing for the purpose of predicting future injury risk is not supported. This finding may seem surprising, but it is consistent with broader literature in sports medicine (Christopher et al., 2019; Bakken et al., 2018). The benefits of strength testing manifest in correlations with sports performance, such as sprinting, jumping, and agility tests (Seitz et al., 2014; Suchomel, Nimphius, and Stone, 2016). Although strength testing does not appear to have value as a predictive tool for injury, strength testing may still be of value for other reasons, such as MOS qualification. Lastly, it is important to note that although strength-event performance does not correlate well with injury risk level, the physiological changes achieved during strength training have been well studied and found to have a favorable impact on sports-injury reduction (Lauersen, Bertelsen, and Andersen, 2014).

Core Strength

Twenty-three included studies assessed core-strength fitness events and injury risk. Seventeen of these studies examined a relationship between initial fitness performance and subsequent injury risk. Core strength was commonly assessed by one or two minutes of sit-ups (14), marching plank test (one), or both (one). One study examined abdominal crunches but found no predictive value with this core strength event. Seven of the studies used the APFT, and eight used other armed services' fitness test batteries, reflecting a common inclusion of core strength in routine PFTs. Despite this common acceptance of core-strength events in military test batteries, predictive value for injury risk was poor.

Results were equivocal among the 17 studies: Six studies found no predictive value from core strength events, and three studies found predictive value from combining core strength performance with other event performance. Eight found that core-strength-event performance was independently predictive of subsequent injury risk.

Results of the unmodified APFT and other military test batteries are covered in the "Periodic Military Physical Fitness Test" section; the remaining five studies using recruit physical assessment tests or modified PFTs are outlined in Table E.7.

The mixed results from core strength testing require better disambiguation prior to using the event to predict future injury risk. The majority of studies examined used some variation of a sit-up test. The sit-up test may be a useful exercise to train for abdominal muscle strength, demonstrates high interrater reliability (Swink et al., 2019), and is a generally feasible test because of low equipment requirements. However, questions remain regarding the applicability of the test results. The sit-up exercise does not isolate abdominal muscles. In fact, the hip flexors muscles are highly active during the sit-up test and produce large shear and compressive forces in the low back (Andersson et al., 1997; Axler and McGill, 1997; Juker et al., 1998; McGill, 1995; Nachemson and Elfström, 1970), which may even cause low-back pain in a subset of people. Additionally, the sit-up test demonstrates poor correlation with sports performance metrics, such as the agility T-test, vertical-jump test, and 40-yard dash test (Shaikh et al., 2019), and there is some evidence that core muscle stability may be a better predictor of injury (De Blaiser, 2018). For the studies that evaluated a sit-up event of one-minute duration, that event is likely insufficient in duration to reach muscle fatigue in many individuals (Knudson and Johnston, 1998).

Table E.7. Summary of Studies of the Predictive Relationship of Injury and Core-Body-Strength Events

Author	Year	Core-Strength Event	Injury Type	APFT or Military PFT?	Concluded Relationship
Knapik et al.	2004	Sit-ups	Any injury	1-1-1 test	The Reception Station PFT consisted of push-ups, sit-ups, and a one-mile run. Compared with individuals who passed the test, those who did not pass the test were 1.6 to 3.9 times more likely to get injured.
Wallace et al.	2006	Sit-ups	EHI	Marine Corps PFT (modified)	Sit-ups were not correlated with subsequent EHI risk in either univariate or multivariate models.
Orr et al.	2020	Sit-ups	Did not specify	Australian Army recruit PFT	A model was developed with fair predictive power that associated higher BMI, female sex, older age, lower initial sit-up performance, and slower initial shuttle-run performance with higher risk for later injury.
Sefton, Lohse, and McAdam	2016	Sit-ups	Overuse and acute MSKI	1-1-1 test	The combined push-up and sit-up score predicted acute MSKI but not overuse MSKI.
Wunderlin et al.	2015	Sit-ups, marching plank	Overuse and acute MSKI	No	The authors concluded that the marching plank test had good results in predicting injuries; however, the receiver operating characteristic (ROC) area under the curve ranged between 0.53 and 0.58 for the sit-up and marching plank test, respectively, indicating poor predictive value.

Slightly fewer than half of the studies evaluating sit-ups and injury prediction used sit-ups as a stand-alone predictor of injury. In the Sefton, Lohse, and McAdam (2016) study, the sit-up event and push-up event were combined to have a predictive power on acute injuries but were not found to have predictive power with overuse injuries. This combination of the sit-up and push-up events may be more indicative of total body strength conditioning and less informative of how core muscle strength relates to injuries. Similarly, Knapik et al.'s 2004 study reviewed the effects of a military fitness test consisting of push-ups, sit-ups, and a one-mile run and found that individuals who failed the test were more likely to get injured. However, the predictive power of a cardiorespiratory event alone is a well-established and strong positive predictor of injury, as mentioned previously, and may disproportionally account for the positive predictive relationship of the combined events and obscure the true predictive value of the sit-up event.

Functional Movement

Functional movement events assess the strength and flexibility of muscle groups over a range of motion and generally correlate with daily tasks, such as overhead weight lifting, load carriage, balancing, or agility with coordination. Eight studies implemented functional movement events, functional fitness elements, or functional movement screening in their studies; however, three did not assess functional movement performance with subsequent injury risk (Teyhen, Rhon, et al., 2016; Teyhen, Shaffer, et al., 2016; Burley et al., 2020). The results of the remaining five studies are reviewed in Table E.8.

Table E.8. Summary of Studies of the Predictive Relationship of Injury and Functional Movement Events

Author	Year	Event Name	Injury Type	APFT or Military PFT?	Concluded Relationship
Wyss et al.	2012	One-leg balance test	Acute and overuse MSKI	Swiss Army PFT	The one-leg balance test was not correlated with subsequent injury risk.
Lisman et al.	2013	FMS	Overuse, traumatic, and any injury	Marine Corps PFT and others	Slower run times were associated with increased injury risk. Multivariate analysis showed slower run times combined with lower functional movement scores increased the predictive value for injury risk.
Grier et al.	2017	Crossover hop, 300-yard shuttle run (weighted), 30-meter up and go (run with weighted vest, helmet, and weapon), agility T-test	Did not specify	APFT and others	For men, injury risk was associated with low performance on a two-mile run (OR slow/fast = 1.51; 95 percent CI: 1.18–1.94) and low performance on a weighted 300-yard shuttle run (OR slow/fast = 1.36; 95 percent CI: 1.06–1.74). For women, injury risk was associated with low performance on the two-mile run (OR slow/fast = 2.38; 95 percent CI: 1.04–5.74). Better performance on a weighted 300-yard shuttle run was correlated with lower injury risk.
Roy et al.	2016	Y-balance composite score, Illinois agility test, weighted step test	Did not specify	APFT and others	Performance on the Illinois agility test and weighted step test were not predictive of subsequent injury risk among deployed female service members. The Y-balance composite score was not related to MSKI in a continuous fashion, but values lower than 95 were associated with a relative injury risk of 1.71 (95 percent CI = 1.13–2.6).
Teyhen et al.	2015	Physical performance measures included ankle	Overuse MSKI	APFT and others	Smoking, prior surgery, recurrent prior injury, limited-duty days in the preceding year because of injury, asymmetrical ankle dorsiflexion, pain with movement on FMS

Author	Year	Event Name	Injury Type	APFT or Military PFT?	Concluded Relationship
		dorsiflexion, FMS, lower- and upper-quarter Y-balance test, and hop testing			clearing tests, and decreased performance on the two-mile run and two-minute sit-up test were associated with increased injury risk.

Studies that incorporated functional movement events had the greatest diversity of event types. Functional events included the one-leg balancing test, crossover hop test, weighted shuttle runs or sprints, agility T-test, and Y-quadrant testing. As a result, it is difficult to conclude whether any of the events can be shown to be predictive of subsequent injury risk because few studies examined the same event.

FMS screening was used in two studies; in one study, a composite score of slower run times and functional movement scores was predictive of subsequent injury risk (Lisman et al., 2013). However, it must be noted that run times are independently predictive of subsequent injury risk. In Teyhen, Shaffer, et al. (2016), asymmetrical ankle range of motion and pain on FMS were predictive of subsequent injury risk. It is possible that asymmetrical ankle range of motion combined with pain-on-movement screens indicate a current but yet-unreported injury and thus is correlated with subsequent medical-seeking behavior for an overuse injury. *It is therefore unclear whether the FMS events are independently able to discern future injury risk* or whether the event detects existing injury.

Performance on balancing tests was evaluated for predictive value for subsequent injury risk in three studies, and one found correlation using the Y-balance test event in a small sample of 41 deployed women (Roy et al., 2016). Others using the Y-balance event or a one-leg standing event found no predictive value for future injury risk (Wyss et al., 2012; Roy et al., 2016; Teyhen et al., 2015).

Weighted movements, such as weighted step tests and shuttle runs performed in body armor, were incorporated in two studies. Roy et al. (2016) did not find a predictive value of the weighted step test with subsequent injury risk, which is surprising given that step tests have been shown to independently predict injury for a wide variety of injury types (Bedno et al., 2013; Bedno et al., 2014; Krauss et al., 2017). Grier et al. (2017) found that, similar to other cardiorespiratory runs and shuttle runs, weighted shuttle runs and sprints were effective at predicting future injury risk.

Height and Weight Relationship with Injury Rates

Although we did not perform a separate literature review specifically searching for a relationship between individual BMI and subsequent injury rates, six of the 41 included articles incidentally reported predictive relationships between an individual's BMI and subsequent injury. This relationship was also found in our analysis presented in Chapter 4.

BMI is the ratio of an individual's weight[31] to the square of their height (CDC, 2022c), which is commonly used to estimate high body fat content. BMI is unable to distinguish between fat and muscle content, and highly muscular individuals will also have a high BMI. However, high body fat content is more common among Americans than is high body muscle, and the amount of body fat has been increasing over time (Grady, 2001).

Relationships between high BMI and subsequent injury rates were consistent among the studies that evaluated this parameter (Grier et al., 2013; Wallace et al., 2006; Bedno et al., 2014; Krauss, 2017; Orr et al., 2020). One study found that training completion rates were predicted by BMI, but injury rates were not significantly correlated ($p = 0.06$; Snoddy and Henderson, 1994).

This relationship was robust for predictive value. The OR for subsequent MSKI increased as BMI increased. ORs for overweight individuals were reported as 1.77 (95 percent CI: 1.29–2.44),[32] and obese individuals had an OR of 2.7 (95 percent CI: 1.67–4.43),[33] when compared with normal-weight individuals (Grier et al., 2013). The analysis presented in Chapter 4 reported a modestly lower OR using a much larger study sample.

These ORs are consistent with those describing increased EHI risk among overweight male Marine Corps recruits (Wallace et al., 2006). Another study on recruits' BMI and EHI found increased risk among obese and underweight individuals but no significant difference between normal and overweight individuals (Bedno et al., 2014). Among female recruits, increased risk for stress fractures and other MSKIs were noted among overweight individuals (Krauss et al., 2017; Allsopp et al., 2003).

This section is limited by the articles selected as part of the original literature search and do not represent the full literature available on BMI and subsequent MSKI. However, *the literature review suggests that BMI can be considered as an independent predictor of subsequent injury risk*, regardless of PFT performance. In our analysis, we also found BMI to be strongly predictive of injury risk.

[31] We used weight to describe the empirical calculation of BMI in our data, but BMI is technically a measure of body mass, with limitations as discussed.

[32] *Overweight* is defined as a those with BMI between 25 and 29 (CDC, 2022b).

[33] *Obese* is defined as those with a BMI above 30 (CDC, 2022b).

Abbreviations

2MR	Two-Mile Run
ACFT	Army Combat Fitness Test
APFT	Army Physical Fitness Test
APHC	U.S. Army Public Health Center
APRT	Army Physical Readiness Training
BMI	body mass index
CDC	Centers for Disease Control and Prevention
CI	confidence interval
DHA	Defense Health Agency
DoD	U.S. Department of Defense
DTIC	Defense Technical Information Center
DTMS	Digital Training Management System
EHI	exertional heat illness
FBI	Federal Bureau of Investigation
FM	field manual
FMS	functional movement screen
H2F	Holistic Health and Fitness
HRP	Hand Release Push-Up—Arm Extension
ICD-10-CM	International Classification of Diseases, Tenth Revision, Clinical Modification
LTK	leg tuck
MDL	3 Repetition Maximum Deadlift
MDR	Military Health System Data Repository
MHS	Military Health System
MOS	military occupational specialty
MSK	musculoskeletal
MSKI	musculoskeletal injury
MTF	military treatment facility
OPAT	Occupational Physical Aptitude Test
OR	odds ratio
PFT	physical fitness test
PLK	Plank
SDC	Sprint-Drag-Carry
SPT	Standing Power Throw

Bibliography

Aker, Janet A., "As Fitness Tests Resume, Troops Seek Post-COVID Exercise Routines," Health.mil, August 31, 2021.

Allsopp, Adrian J., Emily G. Scarpello, S. Andrews, and R. J. Pethybridge, "Survival of the Fittest? The Scientific Basis for the Royal Navy Pre-Joining Fitness Test," *Journal of the Royal Navy Medical Service*, Vol. 89, No. 1, 2003.

Anderson, Morgan K., Tyson Grier, Ester O. Dada, Michelle Canham-Chervak, and Bruce H. Jones, "The Role of Gender and Physical Performance on Injuries: An Army Study," *American Journal of Preventative Medicine*, Vol. 52, No. 5, May 2017.

Andersson, E. A., J. Nilsson, Z. Ma, and A. Thorstensson, "Abdominal and Hip Flexor Muscle Activation During Various Training Exercises," *European Journal of Applied Physiology and Occupational Physiology*, Vol. 75, No. 2, 1997.

APHC—*See* U.S. Army Public Health Center.

Army Regulation 600-9, *The Army Body Composition Program*, Headquarters, Department of the Army, July 16, 2019.

Army Techniques Publication 6-22.5, *A Leader's Guide to Soldier Health and Fitness*, Headquarters, Department of the Army, February 2016.

Army Techniques Publication 7-22.01, *Holistic Health and Fitness Testing*, Headquarters, Department of the Army, October 1, 2020, change 2, August 1, 2022.

Avriette, Mary, Sarah Baker, Chaitra M. Hardison, and Eliot Proctor, *A Governance Framework for the Army Combat Fitness Test: Defining Roles and Responsibilities*, RAND Corporation, RR-A2232-2, forthcoming.

Axler, C. T., and S. M. McGill, "Low Back Loads over a Variety of Abdominal Exercises: Searching for the Safest Abdominal Challenge," *Medicine and Science in Sports and Exercise*, Vol. 29, No. 6, June 1997.

Bakken, Arnhild, Stephen Targett, Tone Bere, Cristiano Eirale, Abdulaziz Farooq, Andrea B. Mosler, Johannes L. Toi, Rod Whiteley, Karim M. Khan, and Roald Bahr, "Muscle Strength Is a Poor Screening Test for Predicting Lower Extremity Injuries in Professional Male Soccer Players: A 2-Year Prospective Cohort Study," *American Journal of Sports Medicine*, Vol. 46, No. 6, May 2018.

Bedno, Sheryl A., David N. Cowan, Nadia Urban, and David W. Niebuhr, "Effect of Pre-Accession Physical Fitness on Training Injuries Among U.S. Army Recruits," *Work*, Vol. 44, No. 4, 2013.

Bedno, S. A., N. Urban, M. R. Boivin, and D. N. Cowan, "Fitness, Obesity and Risk of Heat Illness Among Army Trainees," *Occupational Medicine*, Vol. 64, No. 6, September 2014.

Bigelman, Kevin, "Holistic Health and Fitness (H2F) Implementation," Center for Initial Military Training, U.S. Army, June 2, 2021. As of July 5, 2023:
https://usacimt.tradoc.army.mil/assets/H2F%20101%20(Approved%20for%20Public%20Release).pdf

Breederveld, R. S., J. van Straaten, P. Patka, and J. C. van Mourik, "Immediate or Delayed Operative Treatment of Fractures of the Ankle," *Injury*, Vol. 19, No. 6, 1988.

Burley, Simon D., Jace R. Drain, John A. Sampson, Bradley C. Nindl, and Herbert Groeller, "Effect of a Novel Low Volume, High Intensity Concurrent Training Regimen on Recruit Fitness and Resilience," *Journal of Science and Medicine in Sport*, Vol. 23, No. 10, October 2020.

CDC—*See* Centers for Disease Control and Prevention.

Center for Initial Military Training, *Army Combat Fitness Test: Initial Operational Capability, 1 October 2019 to 30 September 2020*, U.S. Army, October 2019.

Center for Initial Military Training, *U.S. Army Holistic Health and Fitness Operating Concept: The U.S. Army's System for Enhancing Soldier Readiness and Lethality in the 21st Century*, U.S. Army, October 1, 2020.

Center for Initial Military Training, "ACFT 3.0," webpage, U.S. Army, March 23, 2021. As of July 12, 2023: https://www.army.mil/standto/archive/2021/03/23/

Centers for Disease Control and Prevention, "Calculating BMI Using the English System," webpage, last updated February 3, 2022a. As of July 5, 2023: https://www.cdc.gov/nccdphp/dnpao/growthcharts/training/bmiage/page5_2.html

Centers for Disease Control and Prevention, "About Adult BMI," webpage, last updated June 3, 2022b. As of June 22, 2023: https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html

Centers for Disease Control and Prevention, "Body Mass Index (BMI)," webpage, last updated June 3, 2022c. As of June 9, 2023: https://www.cdc.gov/healthyweight/assessing/bmi/index.html

Centers for Disease Control and Prevention, "BRFSS: Table of Overweight and Obesity (BMI)," dataset, October 21, 2022d. As of July 5, 2023: https://chronicdata.cdc.gov/Behavioral-Risk-Factors/BRFSS-Table-of-Overweight-and-Obesity-BMI-/fqb7-mgjf

Centers for Disease Control and Prevention, "Behavioral Risk Factor Surveillance System," webpage, last updated May 17, 2024. As of May 31, 2024: https://www.cdc.gov/brfss/index.html

Childs, John D., Deydre S. Teyhan, Patrick R. Casey, Kimberly A. McCoy-Singh, Angela W. Feldtmann, Alison C. Wright, Jessica L. Dugan, Samuel S. Wu, and Steven Z. George, "Effects of Traditional Sit-Up Training Versus Core Stabilization Exercises on Short-Term Musculoskeletal Injuries in US Army Soldiers: A Cluster Randomized Trial," *Physical Therapy*, Vol. 90, No. 10, October 2010.

Christopher, Shefali M., Jeremy McCullough, Suzanne J. Snodgrass, and Chad Cook, "Do Alterations in Muscle Strength, Flexibility, Range of Motion, and Alignment Predict Lower Extremity Injury in Runners: A Systematic Review," *Archives of Physiotherapy*, Vol. 9, No. 2, February 2019.

Cowan, D. N., S. A. Bedno, N. Urban, B. Yi, and D. W. Niebuhr, "Musculoskeletal Injuries Among Overweight Army Trainees: Incidence and Health Care Utilization," *Occupational Medicine*, Vol. 61, No. 4, June 2011.

Cuddy, John S., Dustin R. Slivka, Walter S. Hailes, and Brent C. Ruby, "Factors of Trainability and Predictability Associated with Military Physical Fitness Test Success," *Journal of Strength and Conditioning Research*, Vol. 25, No. 12, December 2011.

De Blaiser, Cedric, Philip Roosen, Tine Willems, Lieven Danneals, Luc Vanden Bossche, and Roel De Ridder, "Is Core Stability a Risk Factor for Lower Extremity Injuries in an Athletic Population? A Systematic Review," *Physical Therapy in Sport*, Vol. 30, 2018.

Defense Centers for Public Health—Aberdeen, "Periodic Publication—Current Issues," webpage, undated. As of July 12, 2023:
https://phc.amedd.army.mil/news/Pages/PublicationDetails.aspx?type=Health%20of%20the%20Force%20Report

Defense Health Agency—Public Health, "Online Data," webpage, last updated April 18, 2022. As of June 3, 2024:
https://ph.health.mil/topics/campaigns/hof/Pages/Online-Data.aspx

DHA—Public Health—*See* Defense Health Agency—Public Health.

de la Motte, Sarah J., Timothy C. Gribbin, Peter Lisman, Kaitlin Murphy, and Patricia A. Deuster, "Systematic Review of the Association Between Physical Fitness and Musculoskeletal Injury Risk: Part 2—Muscular Endurance and Muscular Strength," *Journal of Strength and Conditioning Research*, Vol. 31, No. 11, November 2017.

de la Motte, Sarah J., Peter Lisman, Timothy C. Gribbin, Kaitlin Murphy, and Patricia A. Deuster, "Systematic Review of the Association Between Physical Fitness and Musculoskeletal Injury Risk: Part 3—Flexibility, Power, Speed, Balance, and Agility," *Journal of Strength and Conditioning Research*, Vol. 33, No. 6, June 2019.

Devi, Sapna, Yannick O. Alexandre, Joon Keit Loi, Ryan D. Gillis, Nazanin Ghazanfari, Sarah J. Creed, Lauren Holz, David Shackleford, Laura K. Mackay, William R. Heath, Erica K. Sloan, and Scott N. Mueller, "Adrenergic Regulation of the Vasculature Impairs Leukocyte Interstitial Migration and Suppresses Immune Responses," *Immunity*, Vol. 54, No. 6, June 2021.

Draicchio, Cathryn, Joel T. Martin, Marcie B. Fyock-Martin, and Justin J. Merrigan, "Retrospective Cohort Analysis of the Army Physical Fitness Test and the Occupational Physical Assessment Test in Reserve Officer Training Corps Cadets: A Brief Report," *Military Medicine*, Vol. 185, Nos. 7–8, August 2020.

Evans, Rachel, Katy Reynolds, Joseph Creedon, and Michelle Murphy, "Incidence of Acute Injury Related to Fitness Testing of U.S. Army Personnel," *Military Medicine*, Vol. 170, No. 12, December 2005.

Field Manual 7-22, *Army Physical Readiness Training*, Headquarters, Department of the Army, October 2012.

Field Manual 7-22, *Holistic Health and Fitness*, Headquarters, Department of the Army, October 2020.

Field Manual 21-20, *Physical Fitness Training*, Headquarters, Department of the Army, September 30, 1992, change 1, October 1, 1998.

FM—*See* Field Manual.

Forrest, Lanna J., Anna Schuh-Renner, Veronique D. Hauschild, Stephen R. Barnes, Tyson L. Grier, Bruce H. Jones, Ryan A. Steelman, Ashleigh McCabe, Esther O. Dada, and Michelle Canham-Chervak, *Estimating the Cost of Injuries Among U.S. Army Soldiers*, U.S. Army Public Health Center, March 1, 2022.

Garber, Carol Ewing, Bryan Blissmer, Michael R. Deschenes, Barry A. Franklin, Michael J. Lamonte, I-Min Lee, David C. Nieman, and David P. Swain, "Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults: Guidance for Prescribing Exercise," *Medicine and Science in Sports and Exercise*, Vol. 43, No. 7, July 2011.

Giovannetti, Jennifer M., Michael Bemben, Debra Bemben, and Joel Cramer, "Relationship Between Estimated Aerobic Fitness and Injury Rates Among Active Duty at an Air Force Base Based upon Two Separate Measures of Estimated Cardiovascular Fitness," *Military Medicine*, Vol. 177, No. 1, January 2012.

Grady, Denise, "The State of Weight: Many Are Too Fat for the Calipers," *New York Times*, January 9, 2001.

Grier, Tyson. L., Michelle Canham-Chervak, Timothy T. Bushman, Morgan K. Anderson, William J. North, and Bruce H. Jones, "Evaluating Injury Risk and Gender Performance on Health- and Skill-Related Fitness Assessments," *Journal of Strength and Conditioning Research*, Vol. 31, No. 4, April 2017.

Grier, Tyson, Michelle Canham-Chervak, Vancil McNulty, and Bruce H. Jones, "Extreme Conditioning Programs and Injury Risk in a US Army Brigade Combat Team," *U.S. Army Medical Department Journal*, October–December 2013.

Guerriere, Katelyn I., Julie M. Hughes, Soothesuk Kusumpa, Leila A. Walker, Melissa D. Richardson, Kathryn M. Taylor, Susan P. Proctor, Stephen A. Foulis, Mary L. Bouxsein, and Kristin L. Popp, "Associations Between Physical Fitness Test Scores and Tibial Bone Microarchitecture in Young Adults Entering Military Training," *Medicine and Science in Sports and Exercise*, Vol. 53, No. 8S, August 2021.

Hardison, Chaitra M., Paul W. Mayberry, Heather Krull, Claude Messan Setodji, Christina Panis, Rodger Madison, Mark Simpson, Mary Avriette, Mark E. Totten, and Jacqueline Wong, *Independent Review of the Army Combat Fitness Test: Summary of Key Findings and Recommendations*, RAND Corporation, RR-A1825-1, 2022. As of June 30, 2023:
https://www.rand.org/pubs/research_reports/RRA1825-1.html

Hauret, Keith G., Michelle Canham-Chervak, Anna Schuh-Renner, Esther O. Dada, Bonnie J. Taylor, Joseph R. Pierce, and Bruce H. Jones, *Injury Surveillance and Longitudinal Studies for Gender Integration in the Army: Second Annual Assessment, 2017*, U.S. Army Public Health Center, No. S.0047783-17, January 2018.

Hauret, Keith G., Ryan A. Steelman, Joseph R. Pierce, Joseph A. Alemany, Marilyn A. Sharp, Stephen A. Foulis, Jan E. Redmond, Maria C. Canino, Bruce S. Cohen, Michale S. McGurk, Whitfield B. East, and Bruce H. Jones, *Association of Performance on the Occupational Physical Assessment Test (OPAT), Injuries, and Attrition During Initial Entry Training—OPAT Phase I*, U.S. Army Public Health Center, No. S.0047229-18b, October 2018.

Hauschild, Veronique D., "Army Health Experts Offer Tips to Prevent ACFT Injuries," U.S. Army Public Health Center, January 2020. As of May 13, 2024:
https://www.usar.army.mil/News/News-Display/Article/2068388/army-health-experts-offer-tips-to-prevent-acft-injuries/

Hauschild, Veronique D., Anna Schuh-Renner, Ashleigh K. McCabe, Keith Hauret, Matthew C. Inscore, Bruce H. Jones, and Michelle Canham-Chervak, *Fiscal Year (FY) 2022 Update: A Taxonomy of Injuries for Public Health Monitoring and Reporting Public Health Information*, U.S. Army Public Health Center, No. 12-01-0717, October 2021.

Hawkins, Jacob, Nicholas A. Andrews, Matthew T. Sankey, Thomas Sanchez, Sean Young, Abhinav Agarwal, Gerald McGwin, and Ashish Shah, "The Impact of Surgical Timing After Ankle Fracture on Clinical and Long-Term Patient Reported Outcomes," *Journal of Foot and Ankle Surgery*, Vol. 23, 2023.

Heller, Rosalie, and H. Stammers, "Running to Breaking Point? The Relationship Between 1.5-Mile Run Time and Injury Risk in Female Recruits During British Army Basic Training," *BMJ Military Health*, Vol. 166, November 2020.

Hicks, Daniel, and Sean Robson, *Implementation of the Army Combat Fitness Test: An Updated Analysis and Future Directions*, RAND Corporation, RR-A2232-1, forthcoming.

Huxel Bliven, K. C., and B. E. Anderson, "Core Stability Training for Injury Prevention," *Sports Health*, Vol. 5, No. 6, 2013.

Juker, D., S. McGill, P. Kropf, and T. Steffen, "Quantitative Intramuscular Myoelectric Activity of Lumbar Portions of Psoas and the Abdominal Wall During a Wide Variety of Tasks," *Medicine and Science in Sports and Exercise*, Vol. 30, No. 2, 1998.

Kimmons, Sean, "Army Combat Fitness Test Set to Become New PT Test of Record in Late 2020," U.S. Army, July 9, 2018. As of July 1, 2020:
https://www.army.mil/article/208189/
army_combat_fitness_test_set_to_become_new_pt_test_of_record_in_late_2020

Knapik, Joseph J., Tyson Grier, Anita Spiess, David I. Swedler, Keith G. Hauret, Bria Graham, James Yoder, and Bruce H. Jones, "Injury Rates and Injury Risk Factors Among Federal Bureau of Investigation New Agent Trainees," *BMC Public Health*, Vol. 11, No. 1, December 2011.

Knapik, J. J., K. G. Hauret, S. Arnold, M. Canham-Chervak, A. J. Mansfield, E. L. Hoedebecke, and D. McMillian, "Injury and Fitness Outcomes During Implementation of Physical Readiness Training," *International Journal of Sports Medicine*, Vol. 24, No. 5, July 2003.

Knapik, Joseph J., Bruce H. Jones, Marilyn A. Sharp, Salima Darakjy, and Sarah Jones, *The Case for Pre-Enlistment Physical Fitness Testing: Research and Recommendations*, U.S. Army Center for Health Promotion and Preventive Medicine, 2004.

Knapik, Joseph J., Marilyn A. Sharp, Michelle Canham-Chervak, Keith Hauret, John F. Patton, and Bruce H. Jones, "Risk Factors for Training-Related Injuries Among Men and Women in Basic Combat Training," *Medicine and Science in Sports and Exercise*, Vol. 33, No. 6, June 2001.

Knapik, Joseph J., Anita Spiess, David Swedler, Tyson Grier, Keith Hauret, James Yoder, and Bruce H. Jones, "Retrospective Examination of Injuries and Physical Fitness During Federal Bureau of Investigation New Agent Training," *Journal of Occupational Medicine and Toxicology*, Vol. 6, No. 26, October 2011.

Knudson, D., "The Validity of Recent Curl-Up Tests in Young Adults," *Journal of Strength and Conditioning Research*, Vol. 15, No. 1, 2001.

Knudson, Duane, and Deborah Johnston, "Analysis of Three Test Durations of the Bench Trunk-Curl," *Journal of Strength and Conditioning Research*, Vol. 12, No. 3, August 1998.

Krauss, Margot R., Nadia U. Garvin, Michael R. Boivin, and David N. Cowan, "Excess Stress Fractures, Musculoskeletal Injuries, and Health Care Utilization Among Unfit and Overweight Female Army Trainees," *American Journal of Sports Medicine*, Vol. 45, No. 2, February 2017.

Lauersen, Jeppe Bo, Ditte Marie Bertelsen, and Lars Bo Andersen, "The Effectiveness of Exercise Interventions to Prevent Sports Injuries: A Systematic Review and Meta-Analysis of Randomised Controlled Trials," *British Journal of Sports Medicine*, Vol. 48, No. 11, 2014.

Lewis, Michael, "PRT: The Army's New Road Map for Physical Readiness," U.S. Army, August 30, 2010. As of July 5, 2023:
https://www.army.mil/article/44456/prt_the_armys_new_road_map_for_physical_readiness

Lisman, Peter, Sarah de la Motte, Timothy Gribbin, Dianna Jaffin, Kaitlin Murphy, and Patricia Deuster, "A Systematic Review of the Association Between Physical Fitness and Musculoskeletal Injury Risk: Part 1—Cardiorespiratory Endurance," *Journal of Strength and Conditioning Research*, Vol. 31, No. 6, 2017.

Lisman, Peter, Francis G. O'Connor, Patricia A. Deuster, and Joseph J. Knapik, "Functional Movement Screen and Aerobic Fitness Predict Injuries in Military Training," *Medicine and Science in Sports and Exercise*, Vol. 45, No. 4, April 2013.

Lovalekar, Mita, Keith Hauret, Tanja Roy, Kathryn Taylor, Sam D. Blacker, Phillip Newman, Ran Yanovich, Chen Fleischmann, Bradley C. Nindl, Bruce Jones, and Michelle Canham-Chervak, "Musculoskeletal Injuries in Military Personnel—Descriptive Epidemiology, Risk Factor Identification, and Prevention," *Journal of Science and Medicine in Sport*, Vol. 24, No. 10, 2021.

Mahlmann, Olivia, Anna Schuh-Renner, and Michelle Canham-Chervak, *Annual Injury Surveillance Report 2021 Summary*, U.S. Army Public Health Center, No. 12-123-0123, January 2023.

McGill, Stuart M., "The Mechanics of Torso Flexion: Situps and Standing Dynamic Flexion Manoeuvres," *Clinical Biomechanics*, Vol. 10, No. 4, 1995.

McGill, Stuart M., "Core Training: Evidence Translating to Better Performance and Injury Prevention," *Strength and Conditioning Journal*, Vol. 32, No. 3, June 2010.

Meadows, Sarah O., Charles C. Engel, Rebecca L. Collins, Robin Beckman, Matthew Cefalu, Jennifer Hawes-Dawson, Molly Doyle, Amii M. Kress, Lisa Sontag-Padilla, Rajeev Ramchand, and Kayla M. Williams, *2015 Department of Defense Health Related Behaviors Survey (HRBS)*, RAND Corporation, RR-1695-OSD, 2018. As of May 14, 2024:
https://www.rand.org/pubs/research_reports/RR1695.html

Meadows, Sarah O., Charles C. Engel, Rebecca L. Collins, Robin L. Beckman, Joshua Breslau, Erika Litvin Bloom, Michael Stephen Dunbar, Mary Lou Gilbert, David Grant, Jennifer Hawes-Dawson, Stephanie Brooks Holliday, Sarah MacCarthy, Eric R. Pedersen, Michael W. Robbins, Adam J. Rose, Jamie Ryan, Terry L. Schell, and Molly M. Simmons, *2018 Department of Defense Health Related Behaviors Survey (HRBS): Results for the Active Component*, RAND Corporation, RR-4222-OSD, 2021. As of May 31, 2024:
https://www.rand.org/pubs/research_reports/RR4222.html

Molloy, Joseph M., Timothy L. Pendergrass, Ian E. Lee, Michelle C. Chervak, Keith G. Hauret, and Daniel I. Rhon, "Musculoskeletal Injuries and United States Army Readiness Part I: Overview of Injuries and Their Strategic Impact," *Military Medicine*, Vol. 185, Nos. 9–10, September–October 2020.

Molloy, Joseph M., Timothy L. Pendergrass, Ian E. Lee, Keith G. Hauret, Michelle C. Chervak, and Daniel I. Rhon, "Musculoskeletal Injuries and United States Army Readiness. Part II: Management Challenges and Risk Mitigation Initiatives," *Military Medicine*, Vol. 185, Nos. 9–10, September–October 2020.

Montero, David, Candela Diaz-Cañestro, and Carsten Lundby, "Endurance Training and V˙O2max: Role of Maximal Cardiac Output and Oxygen Extraction," *Medicine and Science in Sports and Exercise*, Vol. 47, No. 10, 2015.

Nachemson, A., and G. Elfström, "Intravital Dynamic Pressure Measurements in Lumbar Discs: A Study of Common Movements, Maneuvers and Exercises," *Scandinavian Journal of Rehabilitation Medicine Supplement*, Vol. 1, 1970.

National Center for Health Statistics, International Classification of Diseases, Tenth Revision, Clinical Modification, dataset, undated. As of April 29, 2024: https://icd10cmtool.cdc.gov/?fy=FY2024

Orr, Robin M., Bruce S. Cohen, Stephen C. Allison, Lakmini Bulathsinhala, Edward J. Zambraski, and Mark Jaffrey, "Models to Predict Injury, Physical Fitness Failure and Attrition in Recruit Training: A Retrospective Cohort Study," *Military Medicine Research*, Vol. 7, No. 26, June 2020.

Orr, Robin M., Takato Sakurai, Jordan Scott, Jason Movshovich, J. Jay Dawes, Robert Lockie, and Ben Schram, "The Use of Fitness Testing to Predict Occupational Performance in Tactical Personnel: A Critical Review," *International Journal of Environmental Research and Public Health*, Vol. 18, No. 14, July 2021.

Parks, Aaron G., William H. Murrah, Wendi H. Weimar, Paige A. McHenry, Donald Bigham, Kevin Giordano, and Joellen M. Sefton, "Impact of Two Types of Fitness Programs on Soldier Physical Fitness," *International Journal of Exercise Science*, Vol. 15, No. 4, October 2022.

Petosa, Scott, "Women in the Military Academies: US Air Force Academy (Part 2 of 3)," *Physician and Sportsmedicine*, Vol. 17, No. 3, March 1989.

Robson, Sean, Isabel Leamon, Maria C. Lytell, Miriam Matthews, and Margaret Chamberlin, *A Review of the Air Force Fitness Assessment*, RAND Corporation, RR-A762-1, 2021. As of June 13, 2024: https://www.rand.org/pubs/research_reports/RRA762-1.html

Roy, Tanja C., Sara R. Piva, Bryan C. Christiansen, Jonathan D. Lesher, Peter M. Doyle, Rachel M. Waring, James J. Irrgang, Charity G. Moore, Teresa L. Brininger, and Marilyn A. Sharp, "Heavy Loads and Lifting Are Risk Factors for Musculoskeletal Injuries in Deployed Female Soldiers," *Military Medicine*, Vol. 181, Nos. 11–12, November–December 2016.

Russell, Dale W., Joshua Kazman, and Cristel Antonia Russell, "Body Composition and Physical Fitness Tests Among US Army Soldiers: A Comparison of the Active and Reserve Components," *Public Health Reports*, Vol. 134, No. 5, September–October 2019.

Santos, Mayara, Flávia L. Gabani, Selma M. de Andrade, Bruno Bizzozero-Peroni, Vicente Martínez-Vizcaíno, Alberto D González, and Arthur Eumann Mesas, "The Bidirectional Association Between Chronic Musculoskeletal Pain and Sleep-Related Problems: A Systematic Review and Meta-Analysis," *Rheumatology*, Vol. 62, No. 9, 2023.

Schepers, Tim, Mark R. De Vries, Esther M. M. Van Lieshout, and Maarten Van der Elst, "The Timing of Ankle Fracture Surgery and the Effect on Infectious Complications: A Case Series and Systematic Review of the Literature," *International Orthopaedics*, Vol. 37, No. 3, 2013.

Secretary of the Army, "Army Directive 2020-06 (Army Combat Fitness Test)," memorandum, June 12, 2020.

Secretary of the Army, "Army Directive 2022-05 (Army Combat Fitness Test)," memorandum, March 23, 2022.

Secretary of the Army, "Army Directive 2023-08 (Army Body Fat Assessment Exemption for Army Combat Fitness Test Score)," memorandum, March 15, 2023a.

Secretary of the Army, "Army Directive 2023-11 (Army Body Fat Assessment for the Army Body Composition Program," memorandum, June 9, 2023b.

Sefton, JoEllen M., Keith R. Lohse, and Jeremy S. McAdam, "Prediction of Injuries and Injury Types in Army Basic Training, Infantry, Armor, and Cavalry Trainees Using a Common Fitness Screen," *Journal of Athletic Training*, Vol. 51, No. 11, November 2016.

Seitz, Laurent B., Alvaro Reyes, Tai T. Tran, Eduardo Saez de Villarreal, and G. Gregory Haff, "Increases in Lower-Body Strength Transfer Positively to Sprint Performance: A Systematic Review with Meta-Analysis," *Sports Medicine*, Vol. 44, No. 12, 2014.

Shaikh, Anis I., Shibili Nuhmani, Sahaji J. Kachanathu, and Qassim I. Muaidi, "Relationship of Core Power and Endurance with Performance in Random Intermittent Dynamic Type Sports," *Asian Journal of Sports Medicine*, Vol. 10, No. 1, March 2019.

Slentz, Cris A., Joseph A. Houmard, Johanna L. Johnson, Lori A. Bateman, Charles J. Tanner, Jennifer S. McCartney, Brian D. Duscha, and William E. Kraus, "Inactivity, Exercise Training and Detraining, and Plasma Lipoproteins. STRRIDE: A Randomized, Controlled Study of Exercise Intensity and Amount," *Journal of Applied Physiology*, Vol. 103, No. 2, August 2007.

Snoddy, Robert O'Neil, Jr., and John M. Henderson, "Predictors of Basic Infantry Training Success," *Military Medicine*, Vol. 159, No. 9, September 1994.

Suchomel, Timothy J., Sophia Nimphius, and Michael H. Stone, "The Importance of Muscular Strength in Athletic Performance," *Sports Medicine*, Vol. 46, No. 10, 2016.

Swink, C., C. Newton, C. Diehl, J. Moses, J. Hicks, K. G. Lindsay, and J. J. Dawes, "Interrater Reliability of Assessing the Sit-Up Test," *International Journal of Exercise Science: Conference Proceedings*, Vol. 11, No. 7, 2019.

Taylor-Clark, Tanekkia M., Lori A. Loan, Pauline A. Swiger, Larry R. Hearld, Peng Li, and Patricia A. Patrician, "Predictors of Temporary Profile Days Among U.S. Army Active Duty Soldiers," *Military Medicine*, Vol. 188, Nos. 5–6, May–June 2023.

Teyhen, Deydre S., Daniel I. Rhon, Robert J. Butler, Scott W. Shaffer, Stephen L. Goffar, Danny J. McMillian, Robert E. Boyles, Kyle B. Kiesel, and Phillip J. Plisky, "Association of Physical Inactivity, Weight, Smoking, and Prior Injury on Physical Performance in a Military Setting," *Journal of Athletic Training*, Vol. 51, No. 11, November 2016.

Teyhen, Deydre S., Scott W. Shaffer, Robert J. Butler, Stephen L. Goffar, Kyle B. Kiesel, Daniel I. Rhon, Robert E. Boyles, Daniel J. McMillian, Jared N. Williamson, and Phillip J. Plisky, "Application of Athletic Movement Tests That Predict Injury Risk in a Military Population: Development of Normative Data," *Military Medicine*, Vol. 181, No. 10, October 2016.

Teyhen, Deydre S., Scott W. Shaffer, Robert J. Butler, Stephen L. Goffar, Kyle B. Kiesel, Daniel I. Rhon, Jared N. Williamson, and Phillip J. Plisky, "What Risk Factors Are Associated with Musculoskeletal Injury in US Army Rangers? A Prospective Prognostic Study," *Clinical Orthopaedics and Related Research*, Vol. 473, No. 9, September 2015.

U.S. Army, "Army Combat Fitness Test," webpage, undated. As of July 1, 2023:
https://www.army.mil/acft/

U.S. Army, *2021 Health of the Force*, 2021.

U.S. Army, *2022 Health of the Force*, 2022.

U.S. Army Public Health Center, "U.S. Army Injury Surveillance 2018 Summary," briefing, 2018.

U.S. Army Public Health Center, "U.S. Army Injury Surveillance 2021 Summary," briefing, 2021.

U.S. Army Public Health Center, *Estimating the Cost of Injuries Among U.S. Army Soldiers*, No. 12-06-0322, March 2022.

Wallace, Robert F., David Kriebel, Laura Punnett, David H. Wegman, C. Bruce Wenger, John W. Gardner, and John A. Kark, "Risk Factors for Recruit Exertional Heat Illness by Gender and Training Period," *Aviation, Space, and Environmental Medicine*, Vol. 77, No. 4, April 2006.

Wunderlin, S., Lilian Roos, Ralf Roth, Oliver Faude, F. Frey, and Thomas Wyss, "Trunk Muscle Strength Tests to Predict Injuries, Attrition and Military Ability in Soldiers," *Journal of Sports Medicine and Physical Fitness*, Vol. 55, No. 5, May 2015.

Wyss, T., R. O. Von Vigier, F. Frey, and U. Mäder, "The Swiss Army Physical Fitness Test Battery Predicts Risk of Overuse Injuries Among Recruits," *Journal of Sports Medicine and Physical Fitness*, Vol. 52, No. 5, October 2012.

Zigenfus, Gary C., Jiahong Yin, Geneva M. Giang, and W. Tom Fogarty, "Effectiveness of Early Physical Therapy in the Treatment of Acute Low Back Musculoskeletal Disorders," *Journal of Occupational and Environmental Medicine*, Vol. 42, No. 1, 2000.

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The Army Combat Fitness Test (ACFT) became the U.S. Army's physical fitness test of record in October 2022. The test is substantially different from the previous test and consists of six events intended to measure a more expansive set of capabilities: muscular strength and endurance, power, speed, agility, aerobic endurance, balance, flexibility, coordination, and reaction time. One of the Army's stated goals for the test was to reduce preventable injuries. More than half of soldiers experienced a new injury in 2021, so success in reducing the risk of injury could have a significant impact on both medical costs and lost workdays. Because the ACFT has been administered for a relatively short period, there are limited data available to assess the relationship between the ACFT and soldier health and injuries. Nevertheless, this research effort used available data to gain initial insights into this relationship. This study was part of RAND's independent assessment of the ACFT, focusing specifically on injury risk.

To the extent that broader, more-holistic training is motivated by the more-expansive physical requirements of the ACFT, the literature suggests that the ACFT could in the long term lead to an overall reduction in injury rates. Many of the authors' recommendations focus on potential ACFT policy actions that the Army could take to help reduce preventable injuries and assess and monitor soldiers at risk.

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