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The New Army Combat Fitness Test: An Opportunity to Improve Recruitment and Retainment

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Nations have passed away and left no traces,
And History gives the naked cause of it–
One single, simple reason in all cases;
They fell because their peoples were not fit

Rudyard Kipling, preface to *Land and Sea Tales* (published in 1923)

Introduction

On July 5, 1950, Lieutenant Colonel Charles Smith led United States soldiers against an advancing North Korean Army at the Battle of Osan. The US soldiers recently arrived from constabulary duty in Japan, where they had been conducting peacetime service and were not accustomed to Korean mountain combat. The Task Force Smith soldiers became "winded and overwhelmed" as they moved across the hilly terrain (1), and the Army partly attributed the massive casualties resulting from this action to reduced fitness and increasing obesity. This conclusion was reinforced by a landmark study published in 1954 by Kraus and Hirschland (2). Kraus and Hirschland administered an assessment of muscular fitness in American and European children and found that 57.9% of American children failed to pass minimum standards compared with 8.7% of their European counterparts. Given that the US Army recruiting age was (and is) 17, poor childhood fitness affected the ability to recruit a prepared combat-ready force. Task Force Smith shed light on a lack of national attention on fitness. Combined with the findings of Kraus and Hirschland and the Army's need for a physically fit recruiting pool, President Dwight D. Eisenhower established the President's Council on Youth Fitness on July 16, 1956 (1).

The lessons of military readiness garnered from Task Force Smith are used as an example of how the health and fitness of a nation are integral to fielding and training the force for combat (1). Childhood obesity and poor physical fitness are attributes directly related to the inability to recruit and train future soldiers for service in the Army (1). Since the time of Task Force Smith, obesity prevalence has increased, and fitness has declined among draft-age youth. According to a 2017 Pentagon report, 71% of Americans between the ages of 17 and 24 years are ineligible to serve in the military, with obesity as the largest contributing factor (3). The Army Body Composition Program (ABCP), which exists "to ensure all soldiers achieve and maintain optimal well-being and performance under all conditions," requires that potential recruits fall below a published age-dependent BMI threshold (4). To improve military readiness further, the US Army is transitioning to a new physical fitness assessment that evaluates soldier ability to successfully complete the physical demands common to tasks performed in training and in combat.

The ABCP standards brought attention to nutrition and physical activity habits that protected the Army against obesity and improved physical readiness from the pre-standards era before the 1980s. With a recently revamped fitness test, new technologies, and machine learning methods for classifying fitness on a personalized basis, the Army can objectively improve the readiness status of the force.

The Army Combat Fitness Test

Since 1980, the current Army physical fitness assessment, the Army Physical Fitness Test (APFT), has provided insight into soldier fitness trends (5). The test consists of 2 minutes of push-ups and sit-ups and a timed 2-mile run. Push-ups and sit-ups measure upper-body and core muscular endurance, while 2-mile-run performance measures cardiometabolic health. Unfortunately, the APFT was found to be a poor predictor for routine combat tasks (6). The three-event test did not measure ability for lifting and carrying heavy loads, sprinting, and sustained foot marches under heavy loads, which soldiers can expect to perform in combat.

Army researchers determined events that were the strongest predictors of successful performance on Army-related tasks (6). On the basis of this study (6), the Army Combat Fitness Test (ACFT) was developed and will replace the APFT by October 2020. The six ACFT events, conducted in order, include a three-repetition-maximum dead lift, standing power throw, hand-release push-ups, sprint-drag-carry, leg tuck, and 2-mile run. Every soldier must pass established ACFT standards, independent of age or gender.

Mastering the ACFT will require predicting individual poor performance and developing personalized interventions to improve performance. Machine learning methods can be applied directly for this purpose.

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Disclosure: The authors declared no conflicts of interest.

Additional Supporting Information may be found in the online version of this article.

Received: 26 September 2018; **Accepted:** 9 July 2019; **Published online 23 September 2019. doi:10.1002/oby.22619**

Machine Learning Models to Identify Individual Fitness Strengths

We utilized data from the United States Military Academy (USMA) to illustrate how machine learning can aggregate performance data to identify individual strengths and weaknesses. This data set annually records results from the following three standardized physical performance tests: the APFT, the Cadet Fitness Assessment, and the USMA swim test. While we are analyzing physical performance from a highly motivated population at the USMA, similar analysis can also be performed with ACFT success/failure data once enough assessments have been performed.

USMA cadet basic training data

A database of USMA cadet candidate measurements ($n = 8{,}796$) participating in Cadet Basic Training (CBT) was retained from the Class of 2012 to the Class of 2021. The database contained gender, age (years), BMI (weight in kilograms divided by height in meters squared), Cadet Fitness Assessment, APFT, and swim test assessments. We restricted analysis to the length of time to complete a 2-mile run (minutes) and the 150-yard swim (minutes) and the number of push-ups and pull-ups completed within 2 minutes. These variables were selected because the 2-mile run is an ACFT event, pull-ups are the closest CBT assessment to the ACFT leg tucks, and push-ups are closely aligned to hand-release push-ups on the ACFT. The swim test was included because it is an assessment that is uniquely administered at the USMA. The use of these data (Supporting Information Table S1) was approved by the USMA Human Subjects Research Protection Program Protocol #19-010.

Cluster analysis

K-means clustering is a method that partitions a data set into homogenized clusters. The well-established k-means algorithm was developed in 1956. A k-means cluster analysis was performed on the variables age, BMI, length of time to complete a 2-mile run (minutes) and a 150-yard swim (minutes), and the number of push-ups and pull-ups completed within 2 minutes in the statistical software package R version 3.4.4 (R Core; The R Foundation, Vienna, Austria).

A scree plot was applied to determine that the data can be expressed by approximately five clusters. Each resulting cluster can be thought of as a color-coded room containing "similar" individuals. Individuals in each room are similar because they simultaneously have similar age, BMI, length of time to complete a 2-mile run (minutes) and a 150-yard swim (minutes), and number of push-ups and pull-ups completed within 2 minutes.

Because each cluster contains similar individuals based on six different attributes, no simple description characterizing the cluster exists. The strength of the algorithm is that it groups data in a way that is not simply visible. However, cluster summaries (Table 1) and scatterplots reveal cluster characteristics. Figure 1 represents performance on the selected four CBT physical assessments versus BMI, coded by cluster assignment. Although there is not a strong correlation between performance and BMI, performance can be categorized by cluster assignment. For example, in Figure 1A, slower run times are observed in Cluster 5 (purple). In Figure 1B, slower swim times are observed in Cluster 4 (turquoise). Weak push-up performance occurs in Clusters 3 and 5 (Figure 1C). Finally, weak pull-up performance is also observed in Cluster 5 (Figure 1D).

Our data set, unfortunately, does not include many attributes. Cluster analysis and machine learning methods are designed to collapse large data sets with many attributes. Given baseline input variables, such as anthropometric and posture measurements, clustering can determine, from body shape or posture, which individuals are likely to perform poorly on individual ACFT events. With injury outcomes, predicting injury risk can provide a targeted injury prevention program prior to basic training. This is done by first clustering on non-injury-related attributes. Next, the number of injuries is calculated in each cluster. If a cluster contains a high number of injured individuals, cluster membership identifies risk for injury.

Raising the Importance of Physical Fitness in Children

In basic training recruits, there has been a trend in injuries despite BMI bounded by the ABCP limits (5). An established risk factor is low baseline physical fitness (7). Furthermore, individuals who have a history of being physically active are known to sustain fewer injuries (8). While intervention programs implemented prior to basic training can improve fitness among basic training recruits (7), there is no simple correction for the cumulative effects of sedentary behavior during the first 2 decades of biological maturation. As difficult and challenging as it may be, it is imperative for quality military recruitment that we consider improved physical fitness in children.

How to implement policy that increases fitness standards in youth

The Common Core standards in mathematics are specific (9). For example, a high school student is required to "identify zeros of polynomials when suitable factorizations are available and use the zeros to construct

TABLE 1 Summary statistics by cluster number (data are reported as mean ± SD)

Cluster number	*N*	2-mile run (min)	150-yard swim (min)	Push-ups	Pull-ups
1	2,465	12.9 ± 0.8	2.9 ± 0.8	58.2 ± 14.5	12.2 ± 4.7
2	3,437	14.8 ± 0.6	3.2 ± 0.9	52.5 ± 14.5	10.8 ± 5.2
3	1,806	17.1 ± 0.8	3.4 ± .964	40.9 ± 15.2	7.3 ± 5.9
4	404	15.6 ± 2.1	9.2 ± 2.14	49.3 ± 17.2	9.6 ± 5.8
5	492	20.9 ± 2.1	4.0 ± 1.5	30.1 ± 15.6	4.4 ± 5.2

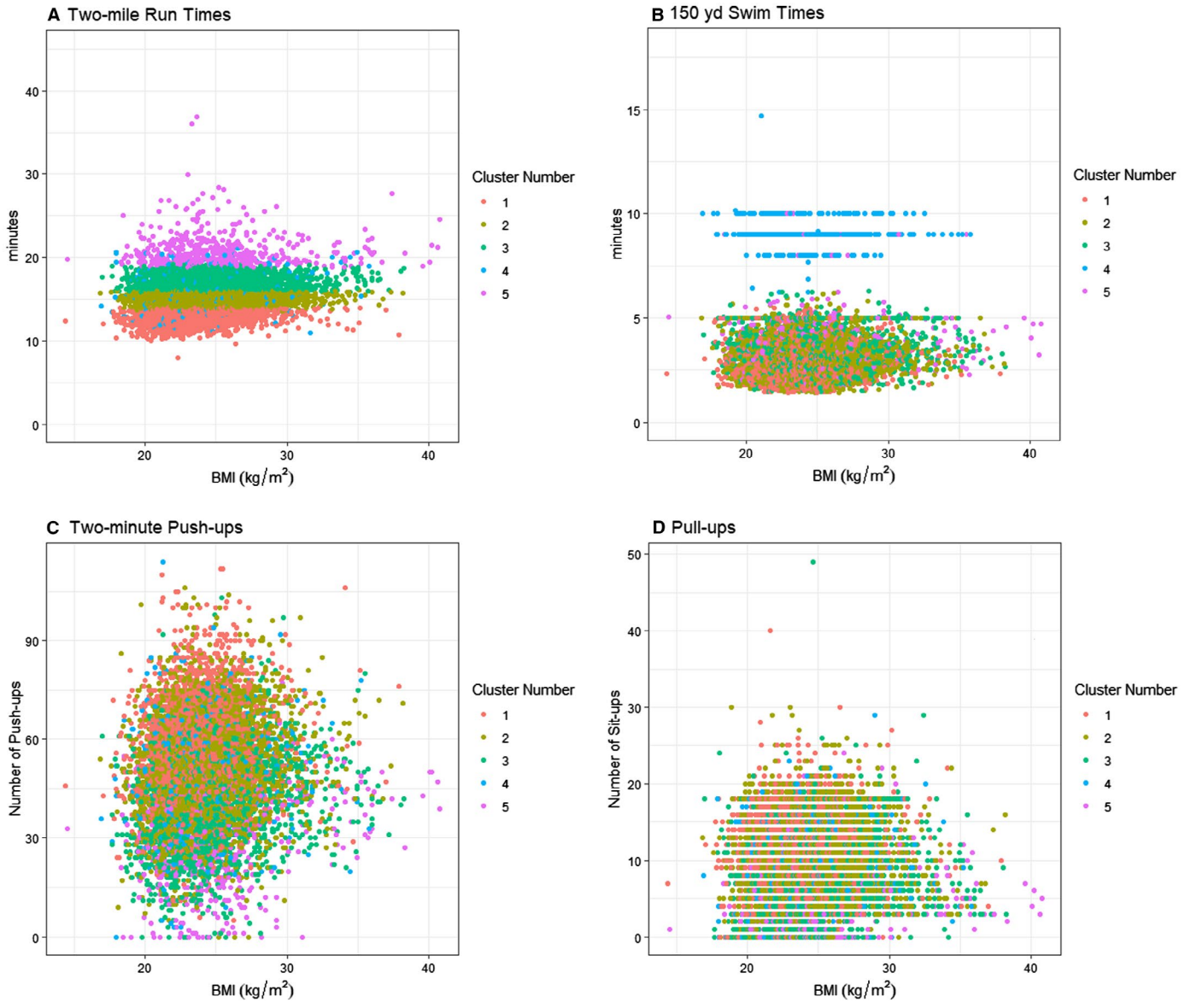

Figure 1 Performance on the four Cadet Basic Training and Cadet Fitness Assessments of **(A)** 2-mile-run times (minutes), **(B)** 150-yard-swim times (minutes), **(C)** 2 minutes of push-ups, and **(D)** 2 minutes of pull-ups versus BMI. Cluster assignment derived from the k-means cluster analysis is color coded within each plot. Different clusters were associated with strong and weak performance in each assessment. Pull-ups and push-ups had the closest agreement of clusters associated with weak performance.

a rough graph of the function defined by the polynomial." In contrast, the national standards provided by the Society of Health and Physical Educators of America are general (10). The five standards are as follows:

Standard 1: The physically literate individual demonstrates competency in a variety of motor skills and movement patterns.
Standard 2: The physically literate individual applies knowledge of concepts, principles, strategies, and tactics related to movement and performance.
Standard 3: The physically literate individual demonstrates the knowledge and skills to achieve and maintain a health-enhancing level of physical activity and fitness.
Standard 4: The physically literate individual exhibits responsible personal and social behavior that respects self and others.
Standard 5: The physically literate individual recognizes the value of physical activity for health, enjoyment, challenge, self-expression, and/or social interaction.

This difference may be because physical education is not always counted toward grade point averages and accountability varies by individual state and national standards.

In fact, physical education could hold students accountable by including remediation for nonmastery, which has been known to improve fitness and reduce injury in basic training recruits (7). The remediation program evaluated by Knapik et al. (7) resulted in lower attrition rates and injury risks compared with a control group. With the advances in wearable technology, students can even be assigned homework to reach step or intensity goals outside of the classroom.

Transition from sports specialization to physical activity at varying levels

With increased attention on athletic scholarships and other benefits of competitive sports in high school, a second alarming trend is the dichotomy of youth sports specialization (11). While such intense specialization may result in high-performing athletes, it also ironically leads to overuse injuries, some of which are irreversible (11). Moreover, the attention on competitive sports results in less gym time and less focus on recreational sports. Sports were intended to be enjoyed; however, the potential for all children to participate in sports is nearly nonexistent.

At the USMA, cadets who are not participating in formal competitive college athletics play recreationally through a program called Company Athletics. The program requires no baseline level of mastery to participate. For example, nonswimmers can participate on the company swim team, and a cadet who is not tall and of average basketball skill can play on the company basketball team.

To make room for recreational play at different levels, our society needs to change the mind-set that all school sports should be competitive with the possibility of leading to membership on collegiate sports teams. Offering gym time for after-school recreational players not participating in school-sponsored competitive programs and/or providing running clubs for children not competing in track or cross country are options that school districts can consider for spreading physical fitness benefits to all children. Additionally, community centers like the YMCA can provide open gym time for recreational activity.

Conclusion

Men and women who join the US Army will fight in continued complex and demanding conflicts. Preparing our soldiers and youth for these conflicts will require novel methods and innovation. Improving physical fitness in our children will ensure a larger recruiting pool for a combat-ready force. Additionally, leveraging data sources provides opportunities to improve military readiness. The number one imperative for the Army remains being ready to deploy, fight, and win our nation's ground wars. Our nation's health forms the foundation of our strong and successful Army.O

Acknowledgments

We would like to thank an anonymous reviewer for editing the manuscript for improved flow. The views expressed in this work are those of the authors and do not reflect the official policy or position of the United States Military Academy, Department of the Army, or the Department of Defense.

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