

THE SCIENCE OF SIT-UPS:

AN ASSESSMENT OF TOTAL PHYSICAL FITNESS

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The effectiveness of Soldiers depends in large part on their physical fitness. Due to the diverse nature of military operations, the Army requires its Soldiers to possess a high level of strength, stamina, agility, resiliency, and coordination which are the factors of physical fitness this study uses for analysis. The Army Physical Fitness Test (APFT) consists of two minutes of push-ups, two minutes of sit-ups, and a two-mile run. Physical readiness training in the Army goes far beyond preparation for the APFT and is focused on a Soldier's total fitness as it relates to combat readiness. The purpose of this study is to determine which events from the APFT — along with pull-ups, a timed obstacle course event, and a foot march — most highly predict a high level of total physical fitness as measured by repetitions or time. The data used to assess these relationships between these events was obtained from the competitive military individual advanced development tryouts conducted at the U.S. Military Academy (USMA) between 2012-2015. Each year of data included six events: push-ups, sit-ups, a run of varying distance, a foot march of varying distance, pull-ups, and USMA's indoor obstacle course. The hypothesis, based on multiple other studies, was that success in foot marching would be a predictor of success in the other physical events tested. This study refuted that hypothesis, however, and statistical analysis suggested the sit-up event was likely the best indicator of total physical fitness.

Background and Assumptions

The Army often conducts physical tests in an attempt to assess fitness. These tests are often conducted at the outset of many competitive Army proficiency schools such as Special Forces Assessment and Selection (SFAS), Ranger School, Sapper School, etc., as well as during Army Basic Combat Training for new enlisted Soldiers. According to Field Manual (FM) 7-22, *Army Physical Readiness Training*, physical development training is meant to prepare "Soldiers and units for the physical challenges of fulfilling the mission in the face of a wide range of threats, in complex operational environments..." Clearly, the focus of physical fitness in the Army is to "meet the



*A Soldier with the 2nd Battalion, 135th Infantry, 1st Brigade Combat Team, 34th Infantry Division completes a ruck march to earn the Expert Infantryman Badge on 27 January 2012.
(Photo by CPL Trisha Betz)*

physical demands of any combat or duty position, accomplish the mission, and continue to fight and win.”¹ This is not an easily quantifiable goal as there are different definitions of fitness, and people have varying opinions on which aspect of fitness is most important. Regardless, the Army’s goal is to measure and quantify a Soldier’s level of fitness and ability “to march long distances in fighting load through rugged country and to fight effectively upon arriving at the area of combat; to drive fast-moving tanks and motor vehicles over rough terrain; to assault; to run and crawl for long distances; to jump in and out of craters and trenches; and to jump over obstacles; to lift and carry heavy objects; to keep going for many hours without sleep or rest.”²

As a result, the needs of the Army demand a multi-faceted approach to fitness. To test the many necessary aspects and levels of a Soldier’s fitness, the Army includes a variety of physical challenges in its physical assessments. At all of the Army schools previously listed, the physical assessments include additional events to the standard APFT such as foot marches, pull-ups, obstacles courses, etc. But, the primary focus of Army training is combat readiness and all of the physical assessments, although varying in length and intensity, attempt to gauge the Soldier’s combat fitness. This study attempts to define which physical tests such as push-ups, pull-ups, a foot march, etc., correlate most highly with a Soldier’s level of total combat physical fitness.

The Army conducts, evaluates, and analyzes various events to assess Soldier fitness. In general, total physical fitness in the Army consists of aerobic and anaerobic activity as well as strength.³ One specific study was conducted at the 75th Ranger Regiment in 1999. According to MAJ Michael Pemrick, a former Ranger company commander who conducted the study on total physical fitness, foot marching “develops all three of the primary physical fitness components” the Army has defined. Because foot marching is a vitally important physical skill for combat arms Soldiers, FM 21-18, *Foot Marches*, recommends a PT program that includes two sessions per week of marching. FM 21-20, *Physical Fitness Training*, claims foot marching is “an excellent aerobic activity” while FM 21-18 states that foot marches meet the requirement for both aerobic endurance and muscular endurance. Others have postulated that foot marching is the best predictor of total physical fitness, and the purpose of this study was to confirm or deny this hypothesis.

It is not only the authors of Army field manuals that consider foot marching an important aspect of physical fitness. In other studies concerning physical fitness in special operations training, foot marching has been seen to be an important indicator of success. Scott Beal, who conducted a study titled “The Roles of Perseverance, Cognitive Ability, and Physical Fitness in U.S. Army Special Forces Assessment and Selection (SFAS),” infers that “physical fitness forms the primary basis upon which SFAS success results.” Based on this conclusion, it is clear the physical testing at SFAS plays a major role in determining the candidates’ success. Of the physical tests conducted, foot marching was the best predictor of success based on analyses of 25 SFAS classes between 1989 and 1991, according to Beal’s study.

Foot marching is not only a test of physical fitness, it is also an effective measure of one’s “grit.” This factor, as described in another study, is one’s level of “central fatigue.” The concept of central fatigue suggests that “fatigue may be controlled by changes in efferent neural command.”⁴ According to this study, “after several hours of repetitive exercise... excitation/contraction coupling failure has been shown to cause fatigue during low intensity training” such as a multiple-hour foot march. But, a lack of “motivational capacity” was also identified as a source of fatigue during these tests. Therefore, a person’s perceived level of fatigue during an event in which there are “several hours of repetitive exercise,” such as a foot march, can be affected by his/her level of motivation.

This mental aspect is a factor when considering one’s physical fitness because it determines a person’s ability and willingness to push the limits of physical ability. A willingness to continually press on regardless of discomfort leads to a higher level of physical fitness from training, as well as a higher level of performance during physical assessments. Because a foot march is a test of physical fitness as well as mental toughness, it is doubly important as any of the other physical tests examined in this study.

In order to improve performance on competitive foot marches, the most effective training regimen does not necessarily need to include frequent foot marches. However, in certain cases such as when a Soldier is preparing to depart for SFAS or Ranger School, it is appropriate to foot march more frequently. The purpose of this specific training is not to increase performance during foot marching, but rather to acclimate the body to long marches. When training for a short and relatively intense physical test, such as the competitive military individual advanced development (MIAD) tryouts, the most effective way to train is to focus on strength and endurance. A proper

training regimen for total body and core strength would consist of compound lifts such as the deadlift, squat, and shoulder press.⁵ In terms of endurance, running, biking, swimming, rowing, and many other cardiovascular workouts are suitable options to increase capacity. Of course, these other activities do not put as much stress on the body and therefore are able to be conducted more frequently than foot marches. Overall, an overly intense schedule of foot marching is not only a sub-optimal training plan; there is also an increased risk of injury as a result of overuse.⁶

Overall, it is clear that Army doctrine and studies conducted in the realm of physical fitness both consider foot marching a strong indicator of total physical fitness. The second assumption in this study is that the series of physical tests used to assess the participants accurately tests the overall physical fitness of the participants. In other words, it is assumed the data used in the study was obtained from a series of physical events (competitive MIAD tryout) that accurately tested a candidate's level of fitness.⁷

Methodology

In order to determine which events are predictors of total physical fitness, the methodology in this study focused solely on the "high performers" or candidates who scored in the top quartile in each event. Because the purpose of this study is to determine which events are predictors of total fitness, it was logical to only focus on the fit candidates. The six events were: 1) West Point's Indoor Obstacle Course Test (IOCT), 2) foot march, 3) push-ups, 4) sit-ups, 5) pull-ups, and 6) 2-mile run. An event was classified as a high-quality predictor of physical fitness if 75 percent or more of the candidates in its top quartile was also above the average in many other events. The proportion of 75 percent was selected as the primary point of analysis because it was a natural break in the results. After initial analysis was conducted, in one-third of all interactions 75 percent of the top quartile in any one event performed above the total average in other events.

The methodology for this study consisted of binning every event in every year into quartiles and then analyzing the results of the top quartile in each event. The data was analyzed on a year-by-year basis because the events in the MIAD tryouts were inconsistent. For example, in 2012 the push-up event was conducted for one minute and in all other years it was two minutes. As a result, the data was binned and compared year by year. The candidates in the top quartile of each event were evaluated against every other event. Their performance in an event was evaluated against the average of the total population in that event. For example, if a candidate scored in the top quartile of the foot march, his performance in the run, IOCT, push-ups, pull-ups, and sit-ups was compared to the average of the total population for those events. If he scored higher than the average of the total population in an event, he was considered above average in that event. The output was the percentage of candidates in a quartile that were above average with respect to another event. This output was generated for each event's top quartile with respect to every other event. An event is considered a high-quality indicator of total fitness if 75 of the candidates in its top quartile are above average in multiple other events.

The performance of the candidate's top quartile in an event was assessed with respect to other events using:

(1) Where:

= the proportion of candidates in the top quartile of event 'x' who performed above average in event 'y'

= the number of candidates in the top quartile of event 'x' who performed above average in event 'y'

= the total number of candidates in the top quartile of event 'x'

Limits of methodology

One significant limit of this methodology is the data analyzed is from assessments that were already conducted before the formulation of this study. As a result, certain components of fitness were not tested as extensively as they should have been. FM 7-22 defines a Soldier's physical condition as strength, stamina, agility, resiliency, and coordination. The MIAD tryouts focused primarily on stamina with the 2 to 5-mile run and foot march. But, the foot march also tests resiliency as described in the study on the concept of central fatigue. The MIAD tryout tested agility and coordination with the obstacle course, upper body and core strength with the push-ups and sit-ups, and strength of back and bicep muscles with pull-ups. This set of events is a valid assessment of combat fitness, but it is possible to make a more comprehensive list of workouts. For example, if the current set of events added a squat of 225 pounds for males and 135 pounds for females, both graded on the number of repetitions completed, a lower body strength component would be added to the fitness assessment. Although the current MIAD assessments did

not directly assess every possible component of total combat fitness, it is still a capable evaluation method.

Another limit of this methodology is that the data for women who tried out for the competitive MIADs was taken differently than their male counterparts. For example, instead of pull-ups, females conducted a flexed arm hang. Because the females were not subject to the same events, there is no valid data on any of the female candidates. As a result, none of the data points from female candidates were analyzed in this study.

Finally, it is important to note the candidates assessed in this study are self-selected to try out for the competitive MIAD opportunities offered at West Point. It is typical that only highly fit, motivated cadets try out for competitive MIADs. Even further, this methodology deals solely with the cadets in the top quartiles of each event. Therefore, this study is dealing strictly with the top performers in an already relatively high performing group. This claim is supported by the fact that the APFT averages of the entire population in every year are over 300 using the West Point extended scale to 375. The total number of data points across the four years of analysis is 914. The only units in the Army in which you can take a random sample size that large and still have an APFT average over 300 are Ranger battalions and Special Forces units. Therefore, the results of this study cannot necessarily be applied to Soldiers with lower levels of physical fitness, only physically high-performing Soldiers because those are the only candidates whose data is analyzed throughout this study.

Results

The cells are highlighted in green if 75 percent or more of the candidates in the top quartile scored higher than the average of the total population in the associated event. For example, in the 2012 data set, 80 percent of the candidates in the foot march top quartile ran the IOCT faster than the average of the total population so that cell is highlighted green. If the percent of candidate's in the top quartile that performed above the average of the total population is between 60 and 75 percent, the cell is highlighted yellow. If that percentage is under 60 percent, the cell is red. The Academic Year (AY) APFT is not considered in this analysis because its three events are being analyzed from the MIAD tryouts. It is safe to assume a high level of performance on the AY APFT would predict high levels of performance on the MIAD push-up, sit-up, and run events.

Analysis

When examining the results of data analysis, it is not clear which events are relatively high-quality predictors of total fitness. In 2012 the most predictive event may seem to be the foot march. The foot march could be determined to be the most predictive because more than 75 percent of the candidates in its top quartile performed above average

		Total Population Events							n	# of events above 75%
2012		AY APFT	IOCT	FM TIME	MIAD PUSH-UP	MIAD SIT-UP	PULL-UPS	MIAD RUN TIME		
Top Quartile Events	IOCT	74.0%		86.0%	60.0%	62.0%	62.0%	76.0%	50	2
	FM TIME	78.2%	81.8%		63.6%	67.3%	52.7%	89.1%	55	3
	MIAD PUSH-UPS	69.1%	76.4%	67.3%		60.0%	63.6%	63.6%	55	1
	MIAD SIT-UPS	73.6%	77.4%	69.8%	67.9%		45.3%	69.8%	53	1
	PULL-UPS	60.8%	84.3%	62.7%	68.6%	56.9%		60.8%	51	1
	MIAD RUN TIME	78.9%	73.7%	91.2%	66.7%	61.4%	54.4%		57	2
2013		AY APFT	IOCT	FM TIME	MIAD PUSH-UP	MIAD SIT-UP	PULL-UPS	MIAD RUN TIME	n	# of events above 75%
Top Quartile Events	IOCT	70.0%		71.7%	61.7%	61.7%	56.7%	78.3%	55	1
	FM TIME	62.7%	84.7%		59.3%	62.7%	59.3%	78.0%	56	2
	MIAD PUSH-UP	80.0%	78.2%	70.9%		90.9%	74.5%	74.5%	61	3
	MIAD SIT-UPS	91.1%	83.9%	75.0%	67.9%		64.3%	89.3%	60	4
	PULL-UPS	63.3%	75.5%	67.3%	83.7%	63.3%		55.1%	59	2
	MIAD RUN TIME	83.6%	90.2%	78.7%	63.9%	72.1%	55.7%		49	3
2014		AY APFT	IOCT	FM TIME	MIAD PUSH-UP	MIAD SIT-UP	PULL-UPS	MIAD RUN TIME	n	# of events above 75%
Top Quartile Events	IOCT	73.7%		73.7%	64.9%	64.9%	54.4%	82.5%	57	1
	FM TIME	72.4%	75.9%		46.6%	62.1%	53.4%	81.0%	58	2
	MIAD PUSH-UP	72.5%	56.9%	72.5%		52.9%	56.9%	80.4%	51	1
	MIAD SIT-UPS	84.3%	76.5%	70.6%	74.5%		76.5%	74.5%	51	3
	PULL-UPS	74.5%	76.6%	59.6%	85.1%	63.8%		68.1%	47	2
	MIAD RUN TIME	77.6%	81.0%	69.0%	56.6%	67.2%	62.1%		58	2
2015		AY APFT	IOCT	FM TIME	MIAD PUSH-UP	MIAD SIT-UP	PULL-UPS	MIAD RUN TIME	n	# of events above 75%
Top Quartile Events	IOCT	60.0%		78.0%	64.0%	64.0%	68.0%	80.0%	50	2
	FM TIME	67.3%	75.0%		63.5%	65.4%	61.5%	82.7%	52	2
	MIAD PUSH-UPS	73.1%	73.1%	69.2%		73.1%	80.8%	67.3%	52	1
	MIAD SIT-UPS	76.0%	70.0%	62.0%	60.0%		68.0%	70.0%	50	1
	PULL-UPS	81.1%	73.0%	59.5%	78.4%	75.7%		64.9%	37	3
	MIAD RUN TIME	69.2%	86.5%	75.0%	59.6%	69.2%	69.2%		52	2

Figure — 2012-2015 Data

in three other events. But, in that same year, being in the top quartile of the foot march was not a predictor at all of how a candidate would perform on the pull-up event as only 52.7 percent of the candidates in the top quartile of foot march completed more than the average number of pull-ups. This leads to the conclusion that while foot march may have been a predictor of certain events in 2012, it was not a predictor of overall fitness. This concept applies throughout all of this analysis. If at least 60 percent of the candidates in an event's top quartile are not above average in every other category, that event is not an indicator of total fitness. In order to be considered a high-quality indicator of total fitness, an event must be able to predict at least marginal success (60 percent of the candidates in the top quartile of the event above the average) with respect to every other event. In 2012, at least 40 percent of the candidates in every event's top quartile performed below average in one other event. In other words, 60 percent or less of the candidates in each event's top quartile performed above average in one other event. Because the candidates in the top quartile of every event performed poorly in one other event, it is helpful to only consider the events with a top quartile in which 75 percent of the candidates perform above average. In 2012, more than 75 percent of the candidates in the foot march event's top quartile performed above average in three other events. As a result, the foot march is considered the best predictor of total physical fitness in 2012.

The 2013 results are much simpler to analyze. More than 75 percent of the candidates in the sit-up event's top quartile performed above average in four other events and at least 60 percent of them performed above average in every event. This leads to the conclusion that the sit-up event is not only the strongest predictor of physical fitness in 2013, but that it is the strongest indicator of physical fitness in any year. The next best predictor of physical fitness in 2013 was the push-up event, but more than 75 percent of the candidates in its top quartile were above average in only three other events. It is interesting to note that foot march is near the bottom in the list of high-quality predictors in 2013. Seventy-five percent of the candidates in its top quartile were above average in only two events. Also, less than 60 percent of them were above average in two events. According to the 2013 data analysis, foot marching is not useful at all to predict a person's total fitness. One could argue that foot marching is in itself an indicator of a person's total fitness because of the importance of foot marching to a Soldier's mission in the Army. This is a valid argument as shown by the research conducted in earlier studies. But, if a person wishes to be considered well-rounded in terms of strength, stamina, agility, resiliency, and coordination, being in the top quartile of the foot marching event must be supplemented by being above average in other events.

In the 2014 data table, similar to the 2013 table, the sit-up event is the most high-quality predictor of total fitness. Not only are more than 75 percent of the candidates in the top quartile of sit-ups above average in three other events (more than any other event's quartile), more than 60 percent of them are above average in every other event. This is unique in the 2014 data because the top quartile of sit-ups is the only quartile that year in which 60 percent of the candidates are above average in every other event. When the results from 2014 are considered in combination with the 2013 data analysis, the data suggests the sit-up event is the most high-quality indicator of total fitness. Although the results are not overwhelming, the sit-up event is the only event that is the most high quality predictor in more than one year.

The argument for sit-ups being the most high-quality predictor of physical fitness is not discredited by the 2015 data results. Although the sit-up event is not the best predictor in 2015, neither is any other event. The only event with more than 75 percent of the candidates in its top quartile above average in three events was the pull-up event, but less than 60 percent of the candidates in the top quartile of the pull-up event were above average in the foot march. So, as described before, the pull-up event is not an indicator of total fitness, just of relatively high performance in a limited group of other events. The 2015 data shows the foot march event as the most potent predictor of total physical fitness as more than 75 percent of the candidates in its top quartile are above average in two other events and more than 60 percent of those candidates are above average in every other event. But, the 2015 data does not show the foot march event as an extremely high-quality predictor because 75 percent or more of the candidates in its top quartile were above average in only two other events. Therefore, when considering all of the available data, it seems that the sit-up event is the most high-quality predictor of total physical fitness. Although this assertion is disputable, the data does lead to that conclusion. Less than 60 percent of the candidates in the top quartile of the sit-up event are above average in only one event throughout the four years of data collecting. That was in the pull-up event in 2012. When comparing the results from all the other events throughout the years, no other event's top quartile performs as consistently above average as the sit-up event's top quartile.

Conclusion

The data collected does not conclusively show one event as the most high-quality predictor of total physical fitness. Based upon a thorough analysis of four years worth of data, the sit-up event is the most high-quality predictor of total physical fitness. This is due to the fact that 60 percent or more of the candidates in the top quartile of the sit-up event are almost always above average in every other event. This fact can be perceived in two ways. The first perspective being if a Soldier is able to perform well on the sit-up event, he is likely to have a high level of total physical fitness. The second conclusion this study could lead to is that if a Soldier performs well on the sit-up event, he likely does not have a low level of fitness. The latter conclusion is much sounder than the former. The candidates in the top quartile of sit-ups were not always top performers in the other events, but they were very rarely below average. The two most important takeaways from this study are summarized in the following points:

- * It was an unexpected result that the sit-up event was the best predictor of total physical fitness. Due to the literature review, the expectation was that the foot march would be the best predictor of total physical fitness.

- * High performance in the sit-up event, especially in the Army, is more than likely a measure of motivation. Generally, in order to perform at a high level on the sit-up event an individual must make a concerted effort to practice sit-ups. This demonstrates an individual's commitment to performing well on physical assessments. Furthermore, those individuals who concern themselves with performing well on physical assessments usually display a high level of total fitness. Sit-ups themselves are not inherently an indicator of total physical fitness; however, an individual that performs well on the sit-up event more than likely has a high level of total physical fitness. Consequently, the sit-up event is an indirect measure of total physical fitness.

It is possible to conduct future research based on the results of this study. One methodology initially attempted in this study was focused on determining which events correlate most highly with total combat physical fitness using single dimensional value functions and multiple correlation analysis. The purpose was to determine how important each event was to total combat physical fitness. But, the model could not be validated, and as a result the methodology was not valid. But, if a similar model that used a candidate's performance in different events as the independent variables and total combat physical fitness as the dependent variable could be validated, that model could result in a better understanding of how important different events are to a Soldier's level of combat fitness.

Based on the results of this study, another possibly beneficial study would be one that defines the relationship between the sit-up event and the other events on the APFT (push-up and run) based on a larger data set that includes both high and low performers. As a result of a more varied data set and larger sample size, such a study may be able to provide more insight into the predictive nature of the sit-up event to a Soldier's total APFT score. This would be valuable information and could possibly lead to changes in the way the Army conducts its physical readiness training.

Notes

¹ FM 7-22, *Army Physical Readiness Training* (Washington, D.C.: Department of the Army, 2012).

² Ibid.

³ Michael Pemrick, "Physical Fitness and the 75th Ranger Regiment: The Components of Physical Fitness and the Ranger Mission," Department of General Studies, U.S. Army Command and General Staff College, Fort Leavenworth, Kan, 1999.

⁴ Alan St Clair Gibson, Michael I. Lambert and Timothy D. Noakes, "Neural Control of Force Output During Maximal and Submaximal Exercise," *Sports Medicine* 31/9 (2001): 637-650.

⁵ Dave Clark, Mike Lambert, and Angus Hunter, "Muscle Activation in the Loaded Free Barbell Squat: A Brief Review," *The Journal of Strength & Conditioning Research* 26/4 (2012): 11-69.

⁶ Nikki Butler, "Injury Prevention as a Combat Multiplier," U.S. Army War College, Carlisle Barracks, PA, 2008.

⁷ MIAD tryouts is a yearly event held at USMA where high performing cadets tryout with their peers for a limited number of slots to prestigious Army schools such as SFAS, Sapper School and Combat Diver Qualification Course.

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Dr. Todd Crowder has been an associate professor in the Department of Physical Education at USMA since 1990. He graduated from Fort Hays State University in 1982 with a bachelor's degree in general science. He also holds a master's degree in exercise physiology and a doctorate of philosophy in human performance from the University of Missouri. Dr. Crowder has also coached Division 1 track for two years at the University of Missouri and nine years at USMA specializing in middle distance events. He has served in a variety of leadership roles and assignments both at USMA and elsewhere. He created the Cadet Fitness Challenge in 2000, and more than 13,000 cadets have been assessed via this comprehensive, criterion based fitness challenge. In 2012, he created the Criterion-Based Military Optimal Performance Challenge. Working and teaming with two Infantry officers, they gathered field data with the 25th Infantry Division, leading to a published article in *Military Medicine*. Currently, Dr. Crowder has created and is working with a Soldier Physical Performance Index, which rank orders Department of Defense personnel with regard to strength, endurance, and mobility.