Physical Fitness Assessments and Injury Risk among U.S. Army Soldiers

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ABSTRACT

Physical fitness assessments are commonly used to determine an athlete's performance abilities. It has been suggested that such assessments can also be used to predict injury risk. **PURPOSE:** To investigate the association of multiple physical fitness assessments with injury risk among U.S. Army Soldiers. **METHODS:** Male Soldiers aged 17-58 years completed the Functional Movement Screening (FMS)™ (n = 1,077), Army Physical Fitness Test (APFT) (n = 1,265), 2-mile run (part of the APFT) (n = 1,537), Y-Balance Test (YBT) (n = 1,135), weighted 300-yard shuttle run (n = 367), un-weighted 300-yard shuttle run (n = 1,125), crossover hop test (n = 1,132), pull-ups (n = 1,033), and vertical jump (n = 1,140). Medical record data for injuries nine months after fitness testing were obtained from the Defense Medical Surveillance System; demographic and health behavior data were collected by survey. A majority of the fitness assessment variables were categorized into quartiles where Q1 = highest performance and Q4 = lowest performance. **RESULTS:** Controlling for age, body mass index (BMI), and smoking; higher injury risk was associated with the un-weighted 300-yard shuttle run (OR≥73.81 seconds (Q4)≤66.00 seconds (Q1)=1.91, 95%CI 1.01-2.22). Controlling for the same variables, higher overuse injury risk was associated with: FMS™ total score (OR15-16 points/19-21 points)=1.71, 95%CI 1.01-2.89), YBT posteromedial difference (OR4.01-7.00 centimeters (Q3)≤2.00 centimeters (Q1))=1.94, 95%CI 1.16-3.23) and (OR≥7.01 centimeters (Q4)≤2.00 centimeters (Q1))=1.73, 95%CI 1.04-2.89), and un-weighted 300-yard shuttle run (OR≥73.81 seconds (Q4)≤66.00 seconds (Q1))=2.07, 95%CI 1.22-3.49). Multivariate odds ratios (OR) and 95% confidence intervals (95% CI) were calculated. **CONCLUSION:** Soldiers with the weakest performance on the un-weighted 300-yard shuttle run, FMS™, and YBT had higher injury risks compared to those in the highest quartile of performance. However, further research is warranted before implementing these tests widely.

INTRODUCTION

Physical fitness assessments are often performed to determine fitness levels and measure changes from training interventions. The Army routinely assesses components of physical fitness as required by the Department of Defense directive 1308.3 (**1**). These components of physical fitness have been broken down by Pate into health- and skill-related components. Health-related components include aerobic endurance, muscular endurance, muscular strength, flexibility, and body composition. Skill-related components consist of agility, balance, coordination, power, speed, and reaction time (**10**). The United States Army currently only assesses three of these components; aerobic endurance, muscular endurance, and body composition. The Army has since begun to question why it is measuring only select fitness components when other health- and skill-related components exist and are possibly relevant indicators of a Soldiers' fitness and readiness for the physical challenges of combat (**4**).

Injuries present a huge problem to the U.S. military, afflicting the health and medical readiness of the Soldier during combat (**2**) and peacetime operations (**6**). Army research and public health investigations have shown that some components of physical fitness are associated with increased risk of musculoskeletal injury. Low aerobic endurance has been the most consistently and strongly related to injury (**3, 7**), while the relation between low muscular endurance and injury risk is only moderately strong (**3**). Body composition and body mass index (BMI) have had inconsistent findings with injury risk (**8**). The purpose of this investigation was to look at the association of multiple fitness components with risk of musculoskeletal injury to determine which assessments are the strongest predictors of injury risk. This paper will focus on the components of aerobic endurance, muscular endurance, body composition, agility, coordination, power, speed, and several non-descript tests.

METHODS

Subjects

Participants were male Soldiers in a U.S. Army Brigade Combat Team (BCT) (n = 4,661). Not all Soldiers completed all of the assessments. Battalions in the BCT consisted of infantry, cavalry, field artillery, brigade support and brigade special troop battalions.

Fitness Assessment Data Collection

Field investigation teams collected fitness data and distributed surveys to the BCT Soldiers. All physical fitness assessments (aside from the 2-mile run, shuttle runs, and vertical jump) were conducted indoors free from environmental elements.

Health-Related Physical Fitness Components

- 2-Mile Run (Aerobic Endurance)
- Army Physical Fitness Test (APFT) (Aerobic Endurance and Muscular Endurance)
- Pull-ups (Muscular Endurance)

Skill-Related Physical Fitness Components

- 300-Yard Shuttle Run (Speed, Agility)
- Crossover Hop Test (Power, Agility)
- Vertical Jump (Power)

Skill-Related Physical Fitness Components (Other)

- Functional Movement Screen (FMS)
- Y-Balance Test (YBT)

Injury Data Collection

Medical record data for Soldiers was obtained from the Defense Medical Surveillance System (DMSS). The injury surveillance period was nine months following initial assessment (April 2011- January 2012). Injury data included all International Classification of Disease (ICD9) inpatient and outpatient injury medical encounters. Injuries were then categorized into the following groups using the primary ICD-9 diagnosis codes: overall injuries and overuse injuries. Overall injuries included all ICD-9 codes related to traumatic and overuse musculoskeletal injuries including environmental injuries. Overuse injuries included those stemming from chronic repetitive movements of the same muscle(s) or muscle group(s) without sufficient rest and recovery that leads to micro trauma.

Data Analyses

Descriptive statistics (frequencies, means and standard deviations) were calculated for performance characteristics, physical fitness and prior injury. A majority of the fitness assessment variables were categorized into quartiles where Q1 = highest 25% of performance and Q4 = lowest 25% of performance. Univariate risk ratios and 95% confidence intervals (95% CI) were calculated for overall and overuse injuries. Multivariate odds ratios (OR) and 95% confidence intervals (95% CI) were calculated for overall and overuse injuries. FMS™ was analyzed according to the standard scale used in the literature (≤14, 15-16, 17-18, 19-21 points) (**5, 9, 11**).

RESULTS

Male Soldiers (age = 26.3 ± 6.3 years, height = 70.1 ± 3.2 inches, weight = 182.6 ± 29.0 pounds, body mass index = 26.0 ± 3.7 kg/m^2) took part in this assessment. Overall injury incidence was 29.0% and overuse injury incidence was 21.5% for the nine-month period.

Table 1 . Demographic risk factors for overall and overuse injuries. For overall injury, African American men had a higher risk of any injury. Regarding overuse injury, men who were over 26 years of age and overweight or obese had a higher risk of overuse injury.

Table 1: Demographic Risk Factors Associated with Injury-Univariate Analysis

Variable	Category of Variable	n	Overall Injuries	Risk Ratio (95% CI)	p-value	Overuse Injuries	Risk Ratio (95% CI)	p-value
Age (years)	≤22	1518	428 (28.2%)	1.00		285 (18.8%)	1.00	
	23-25	1031	284 (27.5%)	0.97 (0.86-1.11)	0.72	217 (21.0%)	1.12 (0.95-1.31)	0.15
	26-29	952	280 (29.4%)	1.04 (0.91-1.18)	0.51	211 (22.2%)	1.18 (1.00-1.38)	**0.04**
	≥30	1160	362 (31.2%)	1.10 (0.98-1.24)	0.09	287 (24.7%)	1.31 (1.14-1.52)	**<0.01**
BMI (kg/m^2)	≤24.9	785	217 (27.6%)	1.00		153 (19.5%)	1.00	
	25-29.9	918	282 (30.7%)	1.11 (0.95-1.29)	0.16	219 (23.9%)	1.22 (1.01-1.47)	**0.02**
	≥30	262	83 (31.7%)	1.14 (0.92-1.41)	0.21	71 (27.1%)	1.39 (1.08-1.77)	**<0.01**
Race	Caucasian	3302	928 (28.1%)	1.00		690 (20.9%)	1.00	
	African American	533	177 (33.2%)	1.18 (1.03-1.34)	**0.01**	120 (22.5%)	1.07 (0.90-1.27)	0.39
	Hispanic	536	168 (31.3%)	1.11 (0.97-1.27)	0.12	127 (23.7%)	1.13 (0.96-1.33)	0.14
	Asian	168	52 (31.0%)	1.10 (0.87-1.38)	0.42	41 (24.4%)	1.16 (0.88-1.53)	0.27
	Other	69	16 (23.5%)	0.83 (0.54-1.28)	0.40	11 (16.2%)	0.77 (0.44-1.33)	0.34
	Unknown	53	13 (24.5%)	0.87 (0.54-1.40)	0.56	11 (20.8%)	0.99 (0.58-1.68)	0.97
Smoking	No	976	286 (29.3%)	1.00		222 (22.7%)	1.00	
	Yes	815	240 (29.4%)	1.00 (0.87-1.16)	0.94	183 (22.5%)	0.98 (0.83-1.17)	0.88

Table 3. Backwards stepping multivariate analysis results using overall injuries as the dependent variable. Variables entered into the model included age, body mass index, smoking, un-weighted 300-yard shuttle run, FMS™ total score, and YBT posteromedial difference. Higher overall injury risk was independently associated with the un-weighted 300-yard shuttle run.

Table 3: Fitness Assessments Associated with Overall Injuries-Multivariate

Variable	Variable Level	N	Odds Ratios (95% CI)	p-value
Un-weighted 300-Yard Shuttle Run (n = 797)	≤66.00 sec	232	1.00	
	66.01-70.20 sec	223	0.96 (0.63-1.46)	0.85
	70.21-73.80 sec	177	1.13 (0.73-1.75)	0.57
	≥73.81 sec	165	1.91 (1.25-2.93)	**<0.01**

Variables entered into model: age, BMI, smoking, un-weighted 300-yard shuttle run, FMS™ total score, and YBT posteromedial difference (from overall injury univariate significance of $p < 0.05$)

Table 4. Backwards stepping multivariate analysis results using overuse injuries as the dependent variable. Variables entered into the model included age, body mass index, smoking, 2-mile run time, un-weighted 300-yard shuttle run, FMS™ total score, and YBT posteromedial difference. Higher overuse injury risk was independently associated with the un-weighted 300-yard shuttle run, FMS™ total score, and YBT posteromedial difference.

Table 4: Fitness Assessments Associated with Overuse Injuries-Multivariate

Variable	Variable Level	N	Odds Ratios (95% CI)	p-value
Un-weighted 300-Yard Shuttle Run (n = 750)	≤66.00 sec	219	1.00	
	66.01-70.20 sec	215	0.91 (0.53-1.55)	0.73
	70.21-73.80 sec	166	1.43 (0.84-2.43)	0.18
	≥73.81 sec	150	2.07 (1.22-3.49)	**<0.01**
FMS™ Total Score (n = 750)	≤14 pts	121	1.56 (0.89-2.73)	0.11
	15-16 pts	146	1.71 (1.01-2.89)	**0.04**
	17-18 pts	246	1.00 (0.61-1.64)	0.98
	19-21 pts	237	1.00	
YBT Posteromedial Difference (n = 750)	≤2.00 cm	247	1.00	
	2.01-4.00 cm	166	1.60 (0.95-2.69)	0.07
	4.01-7.00 cm	166	1.94 (1.16-3.23)	**0.01**
	≥7.01 cm	171	1.73 (1.04-2.89)	**0.03**

Variables entered into model: age, BMI, smoking, 2-mile run time, un-weighted 300-yard shuttle run, FMS™ total score, and YBT posteromedial difference (from overuse injury univariate significance of $p < 0.05$)

Table 2. Univariate analyses for associations of fitness measures with overall and overuse injuries, respectively. For overall injury: a slow un-weighted 300-yard shuttle run, poor FMS™ score, and large YBT posteromedial difference were risk factors for overall injury. For overuse injury: slower 2-mile run times, moderate and slow un-weighted 300-yard shuttle run times, poor performance on the FMS™, and large YBT posteromedial difference were risk factors for overuse injury.

Table 2: Association of Overall and Overuse Injury by Fitness Assessment-Univariate Analysis

Health-Related Physical Fitness Components								
Assessment	**Overall Injury**				**Overuse Injury**			
2-Mile Run	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**
≤14.01 min/sec **(Q1)**	386	25.6%	1		386	17.4%	1	
14.02-15.00 min/sec **(Q2)**	389	29.3%	1.14 (0.90-1.43)	0.25	389	23.9%	1.37 (1.04-1.82)	**0.02**
15.01-16.00 min/sec **(Q3)**	392	30.6%	1.19 (0.95-1.49)	0.12	392	22.7%	1.30 (0.98-1.73)	0.06
≥16.01 min/sec **(Q4)**	370	31.6%	1.23 (0.98-1.54)	0.06	370	25.7%	1.47 (1.12-1.95)	**<0.01**
APFT Total Score	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**
≥276 pts **(Q1)**	308	27.0%	1		308	19.6%	1	
252-275 pts **(Q2)**	319	32.7%	1.20 (0.94-1.53)	0.12	319	23.4%	1.18 (0.87-1.60)	0.26
225-251 pts **(Q3)**	319	25.8%	0.95 (0.73-1.23)	0.72	319	19.9%	1.01 (0.74-1.38)	0.93
≤224 pts **(Q4)**	319	29.6%	1.09 (0.85-1.40)	0.48	319	23.8%	1.20 (0.89-1.62)	0.22
Pull-ups	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**
≤3 reps **(Q1)**	269	32.3%	1.08 (0.83-1.40)	0.54	269	24.2%	1.33 (0.94-1.88)	0.09
4-6 reps **(Q2)**	300	28.0%	0.93 (0.71-1.22)	0.64	300	19.3%	1.07 (0.74-1.52)	0.70
7-9 reps **(Q3)**	226	27.6%	0.93 (0.70-1.24)	0.64	226	19.7%	1.10 (0.75-1.60)	0.61
≥10 reps **(Q4)**	238	29.8%	1		238	18.1%	1	
Skill-Related Physical Fitness Components								
Weighted 300-Yard Shuttle Run	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**
≤75.00 sec **(Q1)**	108	40.7%	1		108	26.9%	1	
75.01-82.20 sec **(Q2)**	99	29.3%	0.71 (0.49-1.05)	0.08	99	22.2%	0.82 (0.51-1.34)	0.44
82.21-91.8 sec **(Q3)**	94	39.4%	0.96 (0.68-1.35)	0.84	94	35.1%	1.30 (0.86-1.98)	0.20
≥91.81 sec **(Q4)**	66	36.4%	0.89 (0.60-1.32)	0.56	66	24.2%	0.90 (0.53-1.53)	0.70
Un-weighted 300-Yard Shuttle Run	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**
≤66.00 sec **(Q1)**	341	26.4%	1		341	16.7%	1	
66.01-70.20 sec **(Q2)**	322	26.9%	1.02 (0.79-1.31)	0.85	322	17.3%	1.04 (0.74-1.45)	0.81
70.21-73.80 sec **(Q3)**	231	32.5%	1.23 (0.95-1.59)	0.11	231	25.5%	1.52 (1.10-2.11)	**0.01**
≥73.81 sec **(Q4)**	231	35.8%	1.36 (1.06-1.74)	**0.01**	231	26.7%	1.60 (1.16-2.20)	**<0.01**
COH Left	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**
≥215 cm **(Q1)**	289	32.8%	1		289	21.0%	1	
194-214 cm **(Q2)**	303	27.4%	0.83 (0.65-1.06)	0.14	303	20.5%	0.96 (0.70-1.32)	0.84
170-193 cm **(Q3)**	290	28.2%	0.86 (0.67-1.10)	0.23	290	18.6%	0.88 (0.63-1.22)	0.45
≤169 cm **(Q4)**	250	30.8%	0.93 (0.73-1.20)	0.60	250	23.2%	1.09 (0.80-1.50)	0.55
COH Right	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**
≥215 cm **(Q1)**	296	31.0%	1		296	19.9%	1	
195-214 cm **(Q2)**	293	27.2%	0.87 (0.68-1.13)	0.31	293	17.0%	0.85 (0.60-1.20)	0.37
172-194 cm **(Q3)**	291	31.6%	1.01 (0.80-1.29)	0.88	291	22.7%	1.13 (0.83-1.55)	0.41
≤171 cm **(Q4)**	253	30.0%	0.96 (0.75-1.24)	0.79	253	24.5%	1.22 (0.89-1.68)	0.19
Vertical Jump	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**
≥25 in **(Q1)**	298	32.1%	1		298	22.1%	1	
23-24 in **(Q2)**	298	27.8%	0.86 (0.67-1.10)	0.24	298	16.7%	0.75 (0.54-1.05)	0.09
21-22 in **(Q3)**	287	31.0%	0.96 (0.75-1.22)	0.75	287	22.6%	1.02 (0.75-1.38)	0.88
≤20 in **(Q4)**	257	29.6%	0.91 (0.71-1.17)	0.50	257	22.6%	1.01 (0.74-1.39)	0.90
Skill-Related Physical Fitness Components (Other)								
FMS™ Total Score	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**
≤14 pts	193	36.8%	1.36 (1.06-1.76)	**0.01**	193	29.4%	1.83 (1.32-2.54)	**<0.01**
15-16 pts	196	30.1%	1.11 (0.84-1.47)	0.42	196	27.0%	1.68 (1.20-2.34)	**<0.01**
17-18 pts	346	29.5%	1.09 (0.86-1.39)	0.45	346	18.2%	1.13 (0.81-1.57)	0.45
19-21 pts	342	26.9%	1		342	16.1%	1	
YBT Anterior Diff.	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**
≤1.00 cm **(Q1)**	284	27.4%	1		284	19.6%	1	
1.01-3.00 cm **(Q2)**	294	29.5%	1.07 (0.83-1.39)	0.57	294	19.3%	0.98 (0.70-1.36)	0.92
3.01-6.00 cm **(Q3)**	308	31.5%	1.14 (0.89-1.47)	0.28	308	23.4%	1.18 (0.86-1.61)	0.28
≥6.01 cm **(Q4)**	251	31.5%	1.14 (0.88-1.49)	0.31	251	22.3%	1.13 (0.81-1.57)	0.46
YBT Posteromedial Diff.	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**
≤2.00 cm **(Q1)**	364	25.5%	1		364	16.5%	1	
2.01-4.00 cm **(Q2)**	267	32.5%	1.27 (0.99-1.63)	0.05	267	22.0%	1.34 (0.97-1.85)	0.07
4.01-7.00 cm **(Q3)**	249	28.8%	1.13 (0.87-1.47)	0.35	249	22.4%	1.36 (0.98-1.89)	0.06
≥7.01 cm **(Q4)**	256	34.0%	1.33 (1.04-1.69)	**0.02**	256	25.8%	1.56 (1.14-2.13)	**<0.01**
YBT Posterolateral Diff.	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**
≤2.00 **(Q1)**	376	31.0%	1		376	21.2%	1	
2.01-4.00 **(Q2)**	244	28.7%	0.92 (0.71-1.18)	0.51	244	19.3%	0.90 (0.65-1.24)	0.54
4.01-7.00 **(Q3)**	254	28.6%	0.92 (0.72-1.18)	0.52	254	21.6%	1.01 (0.75-1.37)	0.90
≥7.01 **(Q4)**	261	30.3%	0.97 (0.76-1.23)	0.81	261	22.6%	1.06 (0.78-1.43)	0.68
Composite Left	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**
≤92.70 **(Q1)**	284	29.9%	1.02 (0.79-1.32)	0.86	284	22.2%	1.19 (0.85-1.66)	0.28
92.71-99.00 **(Q2)**	277	29.6%	1.01 (0.78-1.31)	0.92	277	22.0%	1.18 (0.85-1.66)	0.31
99.01-104.90 **(Q3)**	281	30.7%	1.05 (0.82-1.36)	0.66	281	23.0%	1.24 (0.89-1.73)	0.18
≥104.91 **(Q4)**	270	29.3%	1		270	18.5%	1	
Composite Right	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**	**n**	**Injured (%)**	**Risk Ratio- (95% CI)**	**p-value**
≤93.60 **(Q1)**	276	30.1%	0.94 (0.73-1.21)	0.64	276	22.5%	1.11 (0.80-1.53)	0.50
93.61-99.80 **(Q2)**	282	32.5%	1.02 (0.80-1.30)	0.84	282	24.0%	1.19 (0.87-1.63)	0.26
99.81-105.60 **(Q3)**	281	25.3%	0.79 (0.60-1.03)	0.08	281	19.2%	0.95 (0.68-1.33)	0.78
≥105.61 **(Q4)**	273	31.8%	1		273	20.1%	1	

CONCLUSION

The primary finding in this investigation was the identification of several components of fitness other than aerobic endurance and muscular endurance that were significantly related to injury risk. The un-weighted 300-yard shuttle run, a skills-related component of agility and speed, was the only assessment to have an association with both overall and overuse injury. Soldiers in the lowest quartile of performance on the un-weighted 300-yard shuttle run had approximately twice the risk of overall and overuse injury compared to Soldiers in the highest quartile of performance. In addition, the skill-related components of FMS™ total score and YBT posteromedial difference were also associated with higher risk of overuse injury for those performing poorly.

Caution should be exercised in selecting assessments for testing the components of physical fitness based solely on the significant associations with injury risks. Other important factors to consider include: sensitivity and specificity of the test, cost, equipment, time, training, size of population to be tested, and space available. Assessments such as the FMS™ and YBT require a lot of equipment, are fairly costly to purchase, and require more time and training to implement. It is also unclear what components of fitness these assessments measure. The un-weighted 300-yard shuttle run requires relatively little equipment and training, is easy to implement, and its association with both overall and overuse injury suggest it may be a fitness test to consider implementing in this population. It would also fill a gap in current Army physical fitness testing, which measures only aerobic and muscular endurance.

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