U.S. Army Center for Health Promotion and Preventive Medicine

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Administrative and Safety Evaluation of a Proposed Army Physical Readiness Test (2002)

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Readiness Thru Health

U.S. Army Center for Health Promotion and Preventive Medicine

The lineage of the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) can be traced back over 50 years. This organization began as the U.S. Army Industrial Hygiene Laboratory, established during the industrial buildup for World War II, under the direct supervision of the Army Surgeon General. Its original location was at the Johns Hopkins School of Hygiene and Public Health. Its mission was to conduct occupational health surveys and investigations within the Department of Defense's (DOD's) industrial production base. It was staffed with three personnel and had a limited annual operating budget of three thousand dollars.

Most recently, it became internationally known as the U.S. Army Environmental Hygiene Agency (AEHA). Its mission expanded to support worldwide preventive medicine programs of the Army, DOD, and other Federal agencies as directed by the Army Medical Command or the Office of The Surgeon General, through consultations, support services, investigations, on-site visits, and training.

On 1 August 1994, AEHA was redesignated the U.S. Army Center for Health Promotion and Preventive Medicine with a provisional status and a commanding general officer. On 1 October 1995, the nonprovisional status was approved with a mission of providing preventive medicine and health promotion leadership, direction, and services for America's Army.

The organization's quest has always been one of excellence and the provision of quality service. Today, its goal is to be an established world-class center of excellence for achieving and maintaining a fit, healthy, and ready force. To achieve that end, the CHPPM holds firmly to its values which are steeped in rich military heritage:

- ★ *Integrity is the foundation*
- ★ *Excellence is the standard*
- ★ *Customer satisfaction is the focus*
- ★ *Its people are the most valued resource*
- ★ *Continuous quality improvement is the pathway*

This organization stands on the threshold of even greater challenges and responsibilities. It has been reorganized and reengineered to support the Army of the future. The CHPPM now has three direct support activities located in Fort Meade, Maryland; Fort McPherson, Georgia; and Fitzsimons Army Medical Center, Aurora, Colorado; to provide responsive regional health promotion and preventive medicine support across the U.S. There are also two CHPPM overseas commands in Landstuhl, Germany and Camp Zama, Japan who contribute to the success of CHPPM's increasing global mission. As CHPPM moves into the 21st Century, new programs relating to fitness, health promotion, wellness, and disease surveillance are being added. As always, CHPPM stands firm in its commitment to Army readiness. It is an organization proud of its fine history, yet equally excited about its challenging future.

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13. ABSTRACT *(Maximum 200 words)*

The purpose of this investigation was to perform an administrative and safety assessment of the proposed Army Physical Readiness Test (APRT). Subjects were Ordnance School students in Advanced Individual Training (AIT) at Aberdeen Proving Ground, Maryland. Test items consisted of the standing long jump, power squat, heel hook, 300-yard shuttle run, push-ups and 1-mile run. The procedures followed were those outlined in a draft Army Field Manual 3-22.20 (Physical Readiness Training). A total of 372 soldiers (330 men and 42 women) performed some part of the test but 39 men and 10 women chose not to complete all six events. The majority of men and women who did not complete the testing after starting it complained of being dizzy, "sick" or lightheaded (31%) or of having leg pain (31%). Descriptive statistics and percentile rankings for the 6 events are reported in this paper but limitations of these data include the subject population (young AIT students), the fact that soldiers had no opportunity to practice the test events, and that some soldiers lacked the motivation for the maximal effort required for the test. The APRT required a relatively large amount of equipment. Army warm-up tops were baggy and this made it difficult to observe whether or not soldiers were properly performing the heel hook and push ups. Based on data, test observations, and a review of the literature the following major recommendations were made. Eliminate the heel hook because of the potential for head and spine injury and substitute another test that involves the trunk musculature. Eliminate the power squat because this may encourage soldiers to perform an excessive number of squatting exercises, which may be associated with osteoarthritis. Reduce the number of test events because the fatigue generated by the 6-event test could increase the risk of injury.

14. SUBJECT TERMS
Standing long jump, power squat, heel hook, 300-yard shuttle run, push-ups, 1-mile run, physical fitness, performance, injury

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Table of Contents

Executive Summary

Technical Report No. 12-HF-5738-02
Administrative and Safety Evaluation
Of a Proposed Army Physical Readiness Test

1. Introduction. In June 2001, the U.S. Army Physical Fitness School (USAPFS) requested that Army Center for Health Promotion and Preventive Medicine (USACHPPM) add a proposed Army Physical Readiness Test (APRT) to a study examining injuries and fitness among U.S. Army Ordnance School students. This provided the opportunity to perform an administrative and safety evaluation of the proposed test and this paper describes the results of this effort.

2. Methods. Subjects were Ordnance School students (16th and 143rd Ordnance Battalions) at Aberdeen Proving Ground, Maryland, attending Advanced Individual Training (AIT). All testing was conducted outdoors by technicians and investigators who had been trained on grading and administration of the APRT. Test events included 1) the standing long jump, 2) power squat, 3) heel hook, 4) 300-yard shuttle run, 5) push-ups and 6) a 1-mile run. The procedures followed were those outlined by the USAPFS in a draft Army Field Manual 3-22.20 (Physical Readiness Training). The soldiers were allowed a minimum of 5 minutes and a maximum of 10 minutes rest between events.

3. Results. A total of 372 soldiers (330 men and 42 women) performed all or some part of the test. A total of 39 men (12% of men) and 10 women (24% of the women) chose not to complete all six events. The majority of men and women who did not complete the testing after starting it complained of being dizzy, "sick" or lightheaded (31%), or of having leg pain (31%).

The table shows the descriptive statistics for soldiers who completed all 6 events. Percentile rankings for men and women are also reported in the paper.

Event	Men (N=291)		Women (N=32)	
	Mean	SD	Mean	SD
Standing Long Jump (in)	78.1	10.9	63.8	9.4
Power Squat (reps)	47	7	42	8
Heel Hook (reps)	7	5	1	2
Shuttle Run (sec)	68.9	6.1	77.5	6.2
Push-up (reps)	27	10	11	7
1-Mile Run (min)	7.6	1.0	9.0	1.0

4. Discussion.

a. General. Three considerations limit the generalizaility of the data collected. First, the test sample was a relatively young group of soldiers who volunteered for the study and had been in the military for a very short period of time; therefore, they cannot be considered representive of soldiers in general. Second, soldiers had no opportunity to practice the events prior to the test and it is likely that performance would have been higher if soldiers had been provided time to learn optimal performance strategies. Third, soldiers knew that the test was experimental and not linked to their AIT evaluation and motivational levels varied among soldiers. Because of these limitations, the scores presented here can only be considered very preliminary and not adequate for the development of APRT standards.

(1) The APRT required a relatively large amount of equipment. In our test, this equipment included 2 or 3 measuring tapes, 4 yard sticks, 6 to 8 orange cones, permanently installed pull-up bars, numbered jerseys, stopwatches, clipboards, pencils, water jugs, and cups. Most of this equipment had to be stored, brought out for testing, and accounted for.

(2) Army warm-up jackets and pants were baggy and this made it difficult to observe whether or not soldiers were performing the heel hook and push-ups to the specified standards. On the heel hook, it was difficult to assess whether or not the subjects' arms were fully extended on returning to the starting position. On the push-ups, it was difficult to assess whether or not subjects' arms were parallel to the ground when in the "down" position, whether or not their elbows remained close to the trunk throughout the test, and whether or not the thighs were resting on the ground while attempting to arise from the "down" position.

b. Standing Long Jump. The standing long jump was relatively simple to administer and grade. The distance soldiers landed from the measuring tape varied making it difficult to exactly measure jump distance. Ground conditions were an important factor. Wet and/or slippery conditions increased the risk of slipping and under these conditions soldiers were likely to avoid jumping far to prevent slipping. It is also reasonable to assume that individual performances on the event could be considerably enhanced by practice in the simultaneous use of a bilateral forceful arm swing with the application of lower extremity muscular force.

c. Power Squat. Administration of power squat required observation of a relatively large number of "check points". While a skilled observer could monitor all of these check points, it did require much attention to detail and constant scanning of the body. There was some concern about possible knee problems that could arise if soldiers trained for the event by performing a large number of squats to achieve a high score on the event. High forces are placed on the knee during squatting and the literature indicates that individuals who are engaged in occupations that require prolonged or repetitive squatting and weight training athletes who may perform squatting with heavy loads appear to be at higher risk of knee osteoarthritis. Some squatting exercises, as part of a normal physical activity program, are not contraindicated for individuals with healthy knees. Squatting exercises may improve the strength of the muscle groups involved in the exercise (albeit minimally) and may help soldiers develop motor patterns that will assist them in the correct execution of tasks requiring squatting movements.

d. Heel Hook. The heel hook had the potential to cause serious head or spinal injury if spotters were not attentive and the soldier lost his/her grip on the bar. It is likely that some individuals might risk injury in attempting heel hooks without the aid of spotters while training to improve performance on this task. Spotter safety during the test was of some concern since the soldier being tested was generally swinging his or her legs at a rapid speed. The security of the soldier's grip on the bar was dependent upon the size and condition of the bar. A 1.5 inch bar appeared to provide the best grip. On colder mornings, the bar could be frozen or wet increasing the likelihood of soldiers losing their grip. The use of the black leather glove (without liner) or performance of the test indoors may help with maintaining the grip. About 9% of men and 74% of women could not perform a single heel hook making this test difficult to develop scoring standards. The heel hook was the only test requiring the construction of special equipment (the pull-up bars).

e. 300-Yard Shuttle Run. The 300-yard shuttle run involves a small risk of injury from tripping and falling while running or when stooping to touch the ground and reverse direction. It was difficult for test administrators at the far end of the shuttle run to monitor whether or not the ground was actually touched. One monitor for each runner at the far end of the shuttle run would be optimal. The range of scores on the 300-yard shuttle run was very small. The raw score difference between the 10^{th} and 90^{th} percentile for the men was only 15 seconds and for the women, 14 seconds. With a range this small it will be difficult to establish "points" (as in the current APFT). Also, a small mistake while running (e.g., slip, failure to touch the line) could cause a loss of several seconds resulting in a significantly lowered test score.

f. Push-Ups. It was difficult for soldiers to perform this test correctly, with the elbows close to the trunk. Many soldiers reverted to the techniques of the current push-up and had to be corrected. This is simply a matter of "unlearning" the old push-up techniques.

g. One-Mile Run. By the time soldiers arrive for the 1-mile run, they had performed maximal efforts on 5 prior tests. Soldiers appeared fatigued and many commented they were very tired. The power squats and shuttle run use similar muscle groups of the lower body as does the run. The power squat takes 1 minute to complete while the shuttle run takes 69 and 78 seconds for the average male and female soldier, respectively. Energy sources used on the power squat and shuttle run were likely to be about 65% anaerobic and 35%

aerobic, while the 1-mile run would be expected to be about 20% anaerobic and 80% aerobic (42). Fatigue generated by use of the same muscle groups and use of local energy sources on the power squat and shuttle run may have influenced performance on the 1-mile run.

5. Recommendations.

a. Eliminate the heel hook and substitute another test that involves the trunk musculature. If spotters are inattentive, unable to control a fall, or improperly trained, the potential for head and spinal injury exists.

b. Eliminate the power squat. The activity by itself has minimal risk but the fact that it is a test event may encourage soldiers to train for the event by performing an excessive number of squatting exercises. Prolonged and repetitive squatting may be associated with knee osteoarthritis.

c. Reduce the number of test events. The current test has 6 events and three of which involve lower body anaerobic activity (power squat, shuttle run, 1-mile run) that generates progressive fatigue in this local energy system. This could increase the risk of injury.

d. Give consideration to the difficulties of scoring the shuttle run. The time differences between the 10^{th} and 90^{th} percentile are very small in this study (14-15 seconds). If the assumption is made that the 10^{th} percentile represents passing (the 60 point level) and the 90^{th} percentile the 100 point level, each second in this range represents about 3 points.

e. Allow soldiers to perform the push-up with any hand placement desired thus eliminating the difficult standard of keeping the elbows close to the trunk. Allow the entire 1 minute of test time to complete as many repetitions as possible because it is difficult to determine if soldiers are resting between repetitions or have merely slowed down due to fatigue.

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Technical Report No. 12-HF-5838-02
Administrative and Safety Evaluation
Of a Proposed Army Physical Readiness Test

1. REFERENCES. Appendix A contains the references used in this report.

2. INTRODUCTION.

Tests to evaluate the physical capacity of soldiers have been a long-standing feature of military service. These tests have changed over time as new knowledge has emerged and concepts of physical fitness changed. An early example of a physical fitness evaluation was one proposed by President Theodore Roosevelt (U.S. President between 1901 and 1909) called "Annual Test Ride". This included cavalry marches of not less than 30 miles per day for three days in succession. President Roosevelt called for this test because he felt that "field officers of the line of the Army should be at all times physically fit and able to perform the duties pertaining to their position" (22).

In June 2001, the U.S. Army Physical Fitness School requested that U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) add a proposed Army Physical Readiness Test (APRT) to a collaborative study examining injuries and fitness among Ordnance School students in Advanced Individual Training (AIT). This provided the opportunity to perform an evaluation of the proposed test and this paper describes the results of our evaluation with regard to administrative and safety considerations.

3. BACKGROUND.

At different times, the U.S. Army has used performance tests in an effort to encourage physical training, measure physical fitness, and/or to evaluate physical readiness (3, 6, 9). Early U.S. Army physical training publications (1, 4, 10) contained no physical performance tests. The first published test appeared in the 1941 edition of Army Field Manual (FM) 21-20 (entitled "Physical Fitness"). This FM contained standards for a three-event evaluation that included a 100-yard dash, a running high jump, and a running broad jump (2).

The 1946 edition of FM 21-20 (3) contained a test with a scoring system "to enable the physical training instructor to ascertain the physical condition of the men at the time tested". An "outdoor fitness test" included pull-ups, squat jumps, push-ups, sit-ups and a 300-yard run. An "indoor fitness test" included pull-ups, squat jumps, push-ups, sit-ups, a shuttle run, and a 60-second squat thrust. A scoring system was provided that assigned points (1 to 100) to various performances on each test event. The 1957 edition of FM 21-20 (5) described a 5-event fitness test that included a 40-yard low crawl, horizontal ladder, run-dodge-and-jump, grenade throw, and a 1-mile run. The 1967 edition of FM 21-20 (8) contained an equipment free Minimum Physical Fitness Test involving squat benders, push-ups, sit-ups, leg-overs, squat thrusts, and a stationary run. A separate airborne test involved chin-ups, knee benders, push-ups, sit-ups, and a 1-mile run.

The 1973 edition of FM 21-20 (7) contained a great variety of tests. These tests included the Advanced Physical Fitness Test, Staff and Specialist Fitness Test, Airborne Trainee Physical Fitness Qualification Test, Ranger/Special Forces Physical Fitness Qualification Test, Minimum Physical Fitness Test, Inclement Weather/Limited Facilities Physical Fitness Test, and Basic Physical Fitness Test. Most of these had similar, but not identical events, which included the inverted crawl, sit-ups, push-ups, run-dodge-and-jump, horizontal ladder, 1- or 2-mile run. Point standards were given for many of these tests by age group.

A single APRT appeared in the1980 edition of FM 21-20 (9) replacing the numerous fitness tests in the 1973 manual. The 1980 test consisted of push-ups, sit-ups and a 2-mile run. A point system was provided for both men and women. The 1985 edition of FM 21-20 (9) renamed this test calling it the Army Physical Fitness Test (APFT). The test events and the scoring standards remained the same. The three test items were retained in the 1992 edition of FM 21-20 (6) but higher levels of performance were required for the points. Finally, Change 1 (October 1998) to FM 21-20 upgraded the point standards on the three-event test a second time.

4. Purpose. The purpose of the present study was to examine administrative and safety considerations for the proposed APRT events. We did not evaluate the appropriateness of the individual test items for measuring general physical fitness, specific physical fitness components, or physical readiness.

5. Methods.

a. Subjects. Subjects were Ordnance School students from the 61st Ordnance Brigade (16th and 143rd Ordnance Battalions) at Aberdeen Proving Ground, Maryland. They were attending Advanced Individual Training (AIT) to qualify for a military occupational specialty. Subjects were briefed in several large groups (21 to 65 soldiers) on the purposes and risks of the study. Those that volunteered to participate signed an informed consent statement. An institutional review committee at the U.S. Army Medical Research and Materiel Command approved the research protocol.

b. Procedures.

Soldiers were tested 4-12 days after arrival at Aberdeen Proving Ground, Maryland, shortly after completing Basic Combat Training (BCT). All testing was conducted outdoors by technicians and investigators who had been trained on grading and administration of the test events. Most testers had performed the APRT with graders from the USAPFS. Procedures outlined in a draft of Army Field Manual 3-22.20 were followed. Testing was conducted in the early morning hours between 0500-0630. The test surface was asphalt and testing was conducted under overhead lights because of early morning darkness. Soldiers included in the data analysis were tested in groups ranging in number from 5 to 38. There were a total of 18 separate testing sessions. Soldiers were provided a visual demonstration of each event with a verbal explanation.

Test events (described below) consisted of 1) the standing long jump, 2) 1-minute power squat, 3) 1-minute heel hook, 4) 300-yard shuttle run, 5) 1-minute push-ups and 6) 1-mile run. Soldiers were allowed a minimum of 5 minutes and a maximum of 10 minutes rest between events. Because soldiers were not familiar with the test, if a repetition was performed incorrectly, that repetition was counted as long as the soldier performed the next repetition correctly, after verbal feedback from the grader.

Two test sessions were conducted in wet conditions with soldiers that had been previously tested (n=44). The results of these tests were not included in the numeric data analysis but lessons learned were included in the discussion section of this paper.

c. Test Events

<u>Standing Long Jump</u>. For the standing long jump, the soldier stood behind a line. On the command "Get Set" the soldier assumed a ready stance. On the command "Jump" the soldier had 5 seconds to perform one jump as far forward as possible. They could crouch once or repeatedly as long as they jumped within the prescribed time. The amount and type of arm swing was the choice of the soldier. The scorer marked the distance from the jump line to the landing point of contact nearest the jump line. Soldiers were given two opportunities for this event and scorers recorded the longest of the two jumps.

<u>Power Squat</u>. For the power squat, the command "Get Set" indicated the soldier should assume a straddle stance with hands on hips. On the command, "Go," the soldier repeatedly lowered his/her body by bending at the knees and returned to the starting position by straighening his/her knees. In the fully down position, the soldier's heels remained in contact with the ground, the thighs were parallel with the ground, the arms were extended forward and parallel to the ground with palms facing each other, and the back was straight (though the trunk could be tilted forward at the hip). The soldier had 1 minute to perform as many repetitions as possible. Time remaining was called out by a time keeper every 15 seconds.

<u>Heel Hook</u>. For the heel hook, the soldier mounted one side of a pull-up bar and grasped the bar with an alternating grip such that his/her body faced a supporting posts. On the command "ready, hang", the soldier hung from the bar

with elbows fully extended. On the command "Go", the soldier attempted to raise his/her feet above the bar. Without help from the spotters or supporting bar structures, the soldier was required to either 1) place one foot over the other on top of the bar (hook heels), or 2) place each foot on the bar. The soldier could bend the elbows as much as necessary to assist in obtaining the heel-hook position but must have returned to the starting position with elbows fully extended (no bend) to successfully complete the repetition. The soldier could not rest in the up or down position or the event was terminated. The soldier maintained continuous movement throughout the exercise, except for a slight pause at the heel-hook position necessary to demonstrate that the feet were secured. As long as the soldier was making a valid attempt to attain the heel-hook position, the event was not terminated but no rest was allowed. Two spotters were used, one positioned on each side of the soldier. Spotters ensured safety on the bar. The number of repetitions in 1 minute was counted. Time remaining was called out by a time keeper every 15 seconds.

300-Yard Shuttle Run. For the 300-yard shuttle run, the soldier lined up behind a starting line. On the command "Get Set", soldiers assumed the ready position of his/her choice. On the command, "Go," the soldier ran to a line on the ground 25 yards from the starting line. He/she reached down and touched the line or beyond it with either hand, and then returned to touch a line on the ground at the starting/finish line. This was considered one repetition. The soldier performed a total of six repetitions touching the line at both ends each time. On the last (sixth) repetition, the soldier ran past the starting/finish line without touching it. The grader began recording the time on the command of "Go" and stopped when the soldier crossed the starting/finish line on the sixth repetition. Time was the performance measure and was called out by a single timer as soldiers completed the run.

Push-up. For the push-up, the command "Get Set" indicated the soldier should assume a front leaning rest position. The hands were positioned directly under the shoulders, elbows straight but not locked and pointing backwards, and the feet were together. The body was maintained in a straight line, head to heels. On the command "Go" the soldier lowered his/her body until the upper arm was parallel to the ground, then returned to the starting position. A correct repetition met the following criteria: body maintained in a straight line, upper arms against the trunk with elbows directed to the rear, and upper arms parallel to the ground in the down position with elbows directed to the rear. The number of repetitions in 1 minute was recorded. A timekeeper called out the time remaining every 15 seconds.

1-Mile Run. For the 1-mile run, a measured asphalt course was used. On the command "Get Set" the soldier assumed a ready stance behind a starting line. On the command "Go", the soldier began to run and completed the 1-mile distance. Time to complete the 1-mile distance was recorded. A timekeeper called out times as soldiers completed the run.

d. Data Analysis.

Descriptive statistics (means, standard deviations, percentiles) were calculated by gender for each of the test events. T-tests were used to compare the scores of those completing all test events to those who did not. Tester's observations on each test event were compiled at the end of all testing.

6. Results.

A total of 443 soldiers volunteered for the testing out of the total 770 that were briefed (57% volunteer rate). Because of profiles, soldiers on details, and soldiers who declined participation on the scheduled test day, 372 soldiers (330 men and 42 women) actually performed all or some part of the test. A total of 39 men (12% of men performing the test) and 10 women (24% of the women performing the test) chose not to complete all six test events.

Table 1 shows the number of men and women who did not complete the entire test battery and the specific events they did not complete. The event that most subjects chose not to perform was the 1-mile run. The shuttle run had the second largest number of soldiers who chose not to participate.

Table 1. Number of Soldiers Not Completing Test Events

Gender	Standing Long Jump (n)	Power Squat (n)	Heel Hook (n)	Shuttle Run (n)	Push-ups (n)	1-Mile Run (n)	Not Completing One or More Event (n)
Men	2	4	3	7	3	38	39
Women	0	0	0	5	2	10	10

Subjects expressed reasons for not completing the testing are shown in Table 2. On the first test day, subjects were not asked why they chose not to perform a specific test event and thus we did not obtain reasons for 2 subjects. Some subjects did not provide a reason for failing to complete the test (they just said they did not wish to participate further). Leg pain and the general category of "dizzy, 'sick' and lightheaded" accounted for 61% of all reasons. At least 6 subjects were observed to vomit, usually after the shuttle run or push-ups.

Table 2. Reasons Subjects Expressed For Not Completing Test Events

Reason	Men	Women
Back Pain	1	0
Groin Pain	2	0
Knee Pain	2	1
Leg Pain	10	5
Ankle Pain	2	0
Dizzy, "sick", lightheaded	13	2
Breathing Problem	1	1
Did not want to run	2	0
No reason given	4	1
Did not ask reason	2	0

Table 3 shows the descriptive statistics for soldiers who completed all 6 events. Men's performances exceeded that of the women's on all events with the largest relative difference on the heel hook and the smallest relative difference on the power squat. The average±standard deviation age of the men and women who completed the testing was 19.9±2.6 and 20.0±3.3 years, respectively. The age range was 18 to 32 years for both men and women.

Table 3. Descriptive Statistics for the APRT

Event	Men (N=291)		Women (N=32)	
	Mean	SD	Mean	SD
Standing Long Jump (in)	78.1	10.9	63.8	9.4
Power Squat (reps)	47	7	42	8
Heel Hook (reps)	7	5	1	2
Shuttle Run (sec)	68.9	6.1	77.5	6.2
Push-up (reps)	27	10	11	7
1-Mile Run (min)	7.6	1.0	9.0	1.0

Male percentiles for each event are provided in Table 4 and the percentiles for the women are in Table 5. These percentile rankings include only soldiers who completed all six APRT events. There were fewer percentile rankings for women because of their small number.

Table 4. Male Percentiles for the APRT

Percentiles[a]	Standing Long Jump (in)	Power Squat (reps)	Heel Hook (reps)	Shuttle Run (sec)	Push-ups (reps)	1-Mile Run (min)
Min	43	21	0	57	1	11.1
10	64	40	1	62	15	8.9
20	69	42	2	64	19	8.2
25	71	43	3	64	20	8.0
30	72	44	3	65	21	8.0
40	74	46	5	67	23	7.7
50	77	48	6	68	27	7.5
60	80	49	8	69	30	7.3
70	84	51	10	70	32	7.1
75	86	52	11	71	33	7.0
80	87	54	12	73	35	6.8
90	92	56	15	77	41	6.5
Max	109	67	20	102	61	5.6

[a]Min=Lowest score; Max=Highest score

Table 5. Female Percentiles for the APRT

Percentiles[a]	Standing Long Jump (in)	Power Squat (reps)	Heel Hook (reps)	Shuttle Run (sec)	Push-ups (reps)	1-Mile Run (min)
Min	40	13	0	62	2	11.2
25	58	38	0	74	5	9.8
50	65	42	0	78	11	9.1
75	69	48	1	82	17	8.2
Max	84	56	9	94	26	7.0

[a]Min=Lowest score; Max=Highest score

Table 6 shows a comparison of soldiers who completed all six test events with those who did not complete one or more events. For the men, there was no significant difference between those who did and those who did not complete the test. For the women, there was a tendency for female non-completers to have lower performances but these differences were not large.

Table 6. Comparison of Soldiers Completing and Not Completing Test Events

Event	Status	Men				Women			
		N	Mean[a]	SD[a]	p-value[b]	N	Mean[a]	SD[a]	p-value[b]
Standing Long Jump	Completed	291	78.1	10.9	0.50	32	63.8	9.4	0.11
	Non-Completed	37	79.6	12.8		10	58.1	10.9	
Power Squat	Completed	291	48	7	0.63	32	42	8	0.06
	Non-Completed	35	48	11		10	35	12	
Heel Hook	Completed	291	7	5	0.75	32	1	2	0.74
	Non-Completed	36	8	5		10	1	1	
Shuttle Run	Completed	291	68.9	6.1	0.30	32	77.5	6.2	0.13
	Non-Completed	32	65.9	15.7		5	82.4	9.4	
Push-Ups	Completed	291	27	10	0.59	32	11	7	0.11
	Non-Completed	36	26	10		8	7	5	
1-Mile Run	Completed	291	7.6	1.0	-----	32	9.0	1.0	----
	Non-Completed	1	7.1	-----		0	----	----	

[a]Units of measure are as follows: standing long jump in inches; power squat, heel hook, and push ups are repetitions; shuttle run in seconds; 1-mile run in minutes.
[b]p-value from independent sample t-test

7. Discussion

a. The present study provides a first look at potential scores, percentile rankings and testing considerations (described below) for the proposed APRT. However, there are three serious limitations to the generalizability of these data. First, soldiers who volunteered for this study were recent graduates of BCT who were just beginning Ordnance AIT. The test sample was a group of relatively young soldiers who had been in the military for a very short period of time. Further, only 48% of potential volunteers (372 soldiers of the 770 briefed) were actually tested. Thus, these soldiers cannot be considered representative of soldiers in general. Second, soldiers had no opportunity to practice the events prior to the test. It is likely that performance would have been higher if soldiers had been provided some time to acquire optimal performance strategies (33). Some examples of advantageous performance strategies that we observed included: 1) use of the arms to assist in propelling the body forward on the standing long jump, 2) use of the arms to pull up the body on the heel hook, 3) abrupt deceleration and reversing direction on the shuttle run, 4) pacing throughout the 6-event test to minimize fatigue. A third limitation to the data involves soldier motivation. Since soldiers knew that the test was experimental and was not used in any way to evaluate their performance in AIT, motivation may have been lower than if the test had been included in their AIT evaluation. We observed that the large majority of soldiers were well motivated but a few appeared to be making a minimal effort. Because of these study limitations, the scores presented here should be considered very preliminary and definitely not adequate for the development of standards. When developing actual standards, it will be necessary to test male and female soldiers from all age groups and to provide several sessions to examine how many trials are necessary until performance stabilizes (i.e., until psychomotor learning is minimized).

b. The APRT required a relatively large amount of equipment. For the long jump, we needed 2 to 3 measuring tapes and yard sticks. We used the yard sticks to run a line from each subjects' heels to the tape to accurately measure the jump distance. We needed 6 to 8 orange cones for the shuttle run so soldiers could see the distance they had to run and where the "touch lines" were located. For the heel hook, we constructed pull up bars that had varying distances from the ground because we needed to account for the range of individual heights. There had to be sufficient bars to avoid excessive waiting while performing the test (only 10 minutes maximum is allowed between test events). We needed numbered jerseys to properly identify soldiers on the 1-mile run when we tested larger groups. For proper scoring, we required stopwatches, clipboards, pencils, water jugs and cups. Flashlights were required for safety in the early morning hours. This equipment had to be stored, brought out for testing, returned, and accounted for after testing.

c. Instructions for the heel hook and push ups required subjects to maintain continuous movement thoughout the test (i.e., not to "rest"). However, soldiers would typically stop performing for very short periods of time and it was difficult to determine how long a period of time was "too long". In general, the requirement for "no rest" was loosely enforced during our testing. If this had been more strictly enforced, performances would have been lower.

d. Army warm-up jackets and pants were baggy and this made it difficult to observe whether or not soldiers were properly performing the heel hook and push-ups to precise standards. On the heel hook, it was difficult to assess whether or not arms were fully extended on returning to the starting position. On the push-ups, it was difficult to assess if the subject's arms were parallel to the ground when in the "down" position, if their elbows remained close to the trunk throughout the push-up, and if their thighs were resting on the ground when rising from the "down" position.

e. Considerations for Specific Events

(1) Standing Long Jump

The standing long jump was relatively simple to administer and grade. The use of yard sticks was found to be advantageous to align the soldier's heel with the measurement tape, especially when soldiers landed some distance from the tape. Yet, the further away the subject landed from the tape, the less accurate the measurement due to the difficulty in placing the marking stick perpendicular to the tape. Ground conditions were important. Wet and/or slippery conditions increased the risk of slipping and soldiers jumped cautiously under these conditions to prevent slipping and falling.

It is reasonable to assume that performance on this event could be considerably improved by practice. Use of the arms (to propel the body forward) and optimal timing for the application of muscular force of the leg muscles are two potential performance enhancement strategies.

(2) Power Squat

Administration of power squat required observation of a relatively large number of "check points". These included watching to see whether or not the thigh was parallel to the ground, assuring that the heels did not come off the ground, checking that the arms were extended parallel to the ground and the palms were facing each other, and assuring the soldier returned to the correct starting position (i.e., hands making contact with the iliac crests and knees fully extended). While a skilled observer could monitor all of these check points, it did require constant attention to detail and constant scanning of the entire body of the person being tested.

There was some concern about possible knee problems that could arise if the power squat was included as part of the APRT test battery. The concern was not with the power squat itself, which appears to be a relatively safe exercise, but rather with the repetitive squat training that soldiers may undertake to achieve high scores on the test. Biomechanical considerations (see Appendix B) suggest that high forces are placed on the knee during squatting and these forces might result in long-term damage to particular knee structures. The literature indicates that there is higher risk of osteoarthritis among individuals who engage in occupations that require prolonged or repetitive squatting and among weight training athletes who are likely to perform squatting. A review of the literature on this topic is included in Appendix B.

It should be made clear that squatting exercises, as part of a normal physical activity program, are not contraindicated among individuals with healthy knees. Judiciously applied body weight squatting exercises may prepare soldiers for tasks they must perform as part of their normal occupational activities (e.g., lifting loads, squatting to take cover, examining objects at lower levels).

Body weight squatting will improve the strength of the muscle groups involved in the exercise (albeit minimally) in a very functional way and may help soldiers develop coordinated, multiplanar motor patterns that will assist them in the correct execution of tasks requiring squatting movements. Squatting in the range of 0-50° of knee flexion produces relatively low patellofemoral compressive forces (see Appendix B) and should be acceptable for most individuals. Body weight squatting at knee angles up to 110° should be acceptable for individuals without knee pathologies (17).

(3) Heel Hook

The heel hook had the potential to cause serious head or spinal injury. The event required soldiers to move from a position where they were hanging vertically from a bar (held by their hands, head superior), to a position where their grip on the bar was maintained and their feet interlocked above the bar (head below feet). Spotters were required for this test. However, if the soldier lost his/her grip on the bar and the spotters were not paying attention or not strong enough to catch the soldier, a serious head or spinal injury could have resulted. This did not occur during our testing but it is an eventuality that should be considered.

The safety of the spotters was also of some concern. Tested soldiers often swung up his or her legs at a rapid speed. On at least two occasions soldiers did strike the testers. In these cases, the blows were glancing and did not cause injury but it is possible that a more serious event could occur in future testing.

The security of the soldier's grip on the bar was dependent upon the size and condition of the bar. A 1.5-inch bar appeared to provide the best grip for the largest number of soldiers. On colder mornings, the bar could be frozen or wet increasing the likelihood of soldiers losing their grip. The use of the black leather glove (without liner) helped with maintaining grip under these conditions. The test could be performed indoors to avoid frozen or wet bars.

Technique played a role in the successful execution of the heel hook. Pulling up with the arms at the same time the feet are approaching the top of the bar seemed to improve performance. We observed some individuals who swung (like a pendulum) and this activity was observed to improve performance; this was not prohibited in the test instructions. We also noted a number of individuals who attempted to use the back of the upright post to gain better leverage (although this was not permitted per instructions). Although the test instructions require individuals to return to the "fully hanging" position after each repetition, some individuals were able to avoid detection of their flexed arms within their warm-up jackets.

About 9% of men and 74% of women could not perform a single heel hook. This could make it difficult to develop a "passing" test standard. It is reasonable to assume that after a short period of training many individuals who initially performed no repetitions could perform several. However, because women have considerably less muscle strength compared to men, especially in the upper body (35, 39), there may always be a proportion of women (and some men) who cannot score a single repetition on this test. Depending on the test standards, this may lead to a higher rate of discharges because of soldiers failing the APRT, especially among recruits in BCT.

While some test events (standing long jump, shuttle run) required the purchase of off-the-shelf equipment, the heel hook was the only test requiring the construction of special equipment (the pull up bars). It was the experience of one of the investigators that the fitness test used prior to 1980 required the construction of "Run-Dodge-and-Jump" devices and overhead ladders (5, 7) and some units chose not to perform the entire fitness test because they did not have these devices in place. At the time, the test was not mandatory.

(4) 300-Yard Shuttle Run

The 300-yard shuttle run incurred some risk of injury from tripping and falling during the run or when stopping to touch the ground and reverse direction. We only observed one individual who actually fell and he suffered a minor abrasion on his right hand.

Of all the test events, this was the one most affected by ground conditions. When the ground was wet the participants slowed down, presumably to minimize the risk of slipping and falling.

It was difficult for test administers at the far end of the shuttle run to monitor whether or not the ground was actually touched. We generally had 2-3 individuals at this location and if a large number of individuals had to be monitored (e.g., 8), it was difficult to watch all the soldiers at once. The optimal solution would be to have one monitor for each runner at the far end of the shuttle run course. At the start/finish line we always had a grader and thus monitoring the ground touch was less difficult at this location.

The range of scores on the 300-yard shuttle run was very small. The raw score difference between the 10th and 90th percentile for the men was only 15 seconds and for the women, 14 seconds. In the current APFT there is a 0-100 point system and the 8th percentile represents "passing" (the 60 point level) and the 90th percentile the 100 point level (personal communication with Dr. Louis Tomasi, USAPFS, Ft Benning, Georgia). If similar assumptions are made for the proposed APRT, each second represents about 3 points. A small mistake in running (e.g., slip, failure to touch the line) could result in a loss of several seconds resulting in the loss of many points.

As noted earlier, we observed 6 soldiers who vomited during the testing and this happened most often after the shuttle run and push-ups. These

6 soldiers represent 1.6% of the total group tested but the actual number of soldiers who vomited could have been higher since we did not systematically collect these data. We estimate that the incidence of nausea was much higher but we did not systematically collect these data either. We performed a review of the literature on nausea and vomiting occurring in conjunction with physical activity and our review is at Appendix C.

The APRT has four 1-minute bouts of anaerobic exercise: the power squat, the heel hook, the shuttle run, and the push-ups. The subjects who experienced nausea and vomiting seemed to experience symptoms near the end of the testing, before the 1-mile run. Based on our literature review (Appendix C), we assume that these incidences may be associated with the strenuous anaerobic exercises (power squat, heel hook, shuttle run) that caused mechanical stresses. Mechanical stresses involve the up and down motions on the power squat, inverted motions on the heel hook, and the rapid direction changes and bending to touch the lines on the shuttle run. Also, the repeated shunting of blood away from the gut during exercise and the return of blood to the gut during the rest periods may have played some role but it is not clear from the literature how this might influence subjective symptoms. Gastrointesintal upsets have been related to the consumption of food or fluids in close proximity to physical activity and with dehydration (see Appendix C). However, it is unlikely (though not impossible) that subjects consumed food and/or drink prior to exercise since they had awakened prior to the test and were going to breakfast after completing the test. Also, dehydration down to levels necessary to cause gastrointestinal upsets (see Appendix C) is unlikely since these soldiers probably had adequate fluids the night before and temperatures during the testing period were moderate to very cold.

(5) Push-Ups

It was difficult for soldiers to perform this test correctly. This was most often because soldiers reverted to the techniques of the current push-up and they had to be corrected while the test was underway. For example, when a soldier attempted to rest in the up position they were quickly instructed not to rest but they still benefited from the short rest period. This may simply be a matter of "unlearning" the old push-up techniques. We noticed the body tended to undulate more with this technique than with the push-up used in the current APFT. Also, many soldiers voiced disappointment with their performance on this test compared to push-ups on the current APFT.

(6) 1-Mile Run

By the time soldiers arrived for the 1-mile run, they had performed maximal efforts on 5 prior tests. Soldiers appeared fatigued and many commented they were very tired. The shuttle run and power squat involved similar lower body musculature to the 1-mile run and of special concern was the fatigue induced by the shuttle run. The shuttle run took only 69 and 78 seconds for the average male and female soldier, respectively, to complete. The principle energy sources for the shuttle run were likely to be about 65% anaerobic and 35% aerobic. For the 1-mile run, the predominate energy sources would be expected to be about 20% anaerobic and 80% aerobic (42). Thus, the anaerobic fatigue induced by the shuttle run may have the largest negative influence on the 1-mile run.

The fatigue induced by the 6-event proposed APRT could incur some risk of injury. Short-term fatigue has been shown to effect balance (28) and mechanics of motion (43, 51). During fatigue induced by sprinting, less skilled runners have less extended hips during the latter portion of the stance phase reducing the amount of useful hip and knee moments that can be used for proplusion (51). These gait and balance alterations could place unaccustomed forces on particular portions of the body leading to injury.

(f) Soldiers Who Did Not Complete Testing

Thirteen percent of all soldiers tested chose not to complete the testing. Testing was voluntary and this was made very clear to the volunteers both during the informed consent briefing and during the testing. By far, the test item most soldiers chose not to complete was the 1-mile run. This test came at the end of the test sequence and, as noted above, soldiers seemed very tired. This may have been a factor in soldier's decision not to perform this intense, longer term activity. It is also possible that motivation or the minor physical problems reported by subjects may have played a role in the decision not to perform a particular test event. Pain in specific body regions accounted for 47% of all reasons soldiers provided for discontinuing testing.

The performances of soldiers that did not complete all the tests was similar to those who did (Table 6). This makes it less likely that the soldier's perception of poor performance on prior test events played a major role in his/her decision not to continue with testing.

8. Recommendations.

a. Eliminate the heel hook and substitute another test that more safely assesses the trunk musculature. If soldiers are not attentive, not strong enough to catch a soldier who loses his/her grip, or are untrained, the potential for head and spinal injury exists. The number of repetitions that can be performed is small making scoring difficult. Many individuals, especially women, will not be able to perform a single repetition. This could lead to a high rate of discharges for failure to pass the test.

b. Eliminate the power squat. The activity by itself has minimal risk but the fact that it is a test event may encourage soldiers to perform an excessive number of squatting exercises. Prolonged and repetitive squatting may be associated with knee osteoarthritis.

c. Reduce the number of test events. The current test has 6 events and three of these involve lower body anaerobic activity (power squat, shuttle run, 1-mile run) that generates progressive fatigue in this local energy system. This could increase the risk of injury due to altered body mechanics.

d. Consideration should be given to scoring the shuttle run. The time differences between the 10^{th} and 90^{th} percentile are very small in this study (14-15 seconds). If the assumption is made that the 8^{th} percentile represents passing (the 60 point level) and the 90^{th} percentile the 100 point level, each second in this range represents about 3 points. Small errors on the test could lead to the loss of many points.

e. Allow soldiers to perform the push-up with any hand placement desired thus removing the difficult standard of keeping the elbows close to the trunk. Allow the entire 1 minute of test time to complete as many repetitions as possible by allowing approved rest positions. It is difficult to determine if soldiers are truly resting between repetitions or have merely slowed down due to fatigue.

APPENDIX A

References

1. U.S. Army. *Calisthenic Exercises*. Washington DC: US Government Printing Office, 1892
2. U.S. Army. *Field Manual 21-20. Physical Training*. Washington DC: US Government Printing Office, 1941
3. U.S. Army. *Field Manual 21-20. Physical Training*. Washington DC: US Government Printing Office, 1946
4. U.S. Army. *Manual of Physical Training*. Washington DC: US Government Printing Office, 1914
5. U.S. Army. *Physical Conditioning*. Washington DC: Headquarters, Department of the Army, 1957
6. U.S. Army. *Physical Fitness Training. U.S. Army Field Manual (FM) 21-20.* Washington, D.C.: Headquarters, Department of the Army, 1992
7. U.S. Army. *Physical Readiness Training*. Washington DC: Headquarters, Department of the Army, 1973
8. U.S. Army. *Physical Readiness Training*. Washington DC: Headquarters, Department if the Army, 1969
9. U.S. Army. *Physical Readiness Training*. Washington DC: Headquarters, Department of the Army, 1980
10. U.S. Army. *Training Regulation No. 115-5: Physical Training*. Washington DC: War Department, 1928
11. Brouns, F. and E. Beckers. Is the gut an athletic organ? Digestion, absorption and exercise. *Sports Med*. 15:242-257, 1993.
12. Cavanagh, P. R. and M. A. LaFortune. Ground reaction forces in distance running. *J Biomech*. 13:397-406, 1980.
13. Clark, C. S., B. Kraus, J. Sinclair, and D. Castell. Vigorous exercise induces gastroesophageal reflux (GER). *Gastroenterol*. 94:A612, 1988.
14. Coggon, D., P. Croft, S. Kellingray, D. Barrett, M. McLaren, and C. Cooper. Occupational physical activities and osteoarthritis of the knee. *Arthritis Rheum*. 43:1443-1449, 2000.
15. Dahlkvist, N. J., P. Mayo, and B. B. Seedhom. Forces during squatting and raising from a deep squat. *Eng Med*. 11:69-76, 1982.
16. Dickinson, J. A., S. D. Cook, and T. M. Leinhardt. The measurement of shock waves following heel strike while running. *J Biomech*. 18:415-422, 1985.
17. Escamilla, R. F. Knee biomechanics of the dynamic squat exercise. *Med Sci Sports Exerc*. 33:127-141, 2001.
18. Escamilla, R. F., G. S. Fleisig, N. Zheng, S. W. Barrentine, K. E. Wilk, and J. R. Andrews. Biomechanics of the knee during closed kinetic chain and open kinetic chain exercises. *Med Sci Sports Exerc*. 30:556-569, 1998.
19. Escamilla, R. F., N. Zheng, G. S. Fleisig, J. E. Lander, S. W. Barrentine, G. R. Cutter, and J. R. Andrews. The effect of technique variation on knee

biomechanics during the squat and leg press. *Med Sci Sports Exerc.* 29 (Suppl 5):S156, 1997.

20. Felson, D. T., M. T. Hannan, A. Naimark, J. Berkeley, G. Gordon, P. W. F. Wilson, and J. Anderson. Occupational physical demands, knee bending, and knee osteoathritis: results from the Framingham study. *J Rheumatol.* 18:1587-1592, 1991.
21. Frederick, E. C., J. L. Hagy, and R. A. Mann. The prediction of vertical impact forces during running. *J Biomech.* 14:498, 1981.
22. Friedl, K. E. Body composition and military performance: origins of the Army standards. In: *Body Composition and Military Performance*. B. M. Marriott and J. Grumstrup-Scott (Eds.) Washington, DC: National Academy Press, 1992, pp. 31-55.
23. Fu, F. H., M. J. Seel, and R. A. Berger. Patellofemoral biomechanics. In: *The Patellofemoral Joint*. J. M. Fox and W. DelPizzo (Eds.) New York: McGraw-Hill, 1993, pp. 49-62.
24. Gabiner, M. D., T. J. Koh, and L. Draganich. Neuromechanics of the parellofemoral joint. *Med Sci Sports Exerc.* 26:10-21, 1994.
25. Gil, S. M., E. Yazaki, and D. F. Evans. Aetiology of running-related gastrointestinal dysfunction. *Sports Med.* 26:365-378, 1998.
26. Halvorsen, F. A., J. Lyng, T. Glomsaker, and S. Ritland. Gastrointestinal disturbances in marathon runners. *Br J Sports Med.* 24:266-268, 1990.
27. Jensen, L. K. and W. Eenberg. Occupation as a risk factor for knee disorders. *Scand J Work Environ Health.* 22:165-175, 1996.
28. Johnson, R. B., M. E. Howard, P. W. Cawley, and G. M. Losse. Effect of lower extremity muscular fatigue on motor control performance. *Med Sci Sports Exerc.* 30:1703-1707, 1998.
29. Keeffe, E. B., D. K. Lowe, G. R, and R. Wayne. Gastrointestiinal symptoms of marathon runners. *West J Med.* 141:481-484, 1984.
30. Knapik, J. J., P. Ang, K. Reynolds, and B. Jones. Physical fitness, age and injury incidence in infantry soldiers. *J Occ Med.* 35:598-603, 1993.
31. Knapik, J. J., M. L. Canham-Chervak, R. McCollam, S. Craig, and E. Hoedebecke. *An investigation of injuries among officers attending the US Army War College during Academic Year 1999.* Aberdeen Proving Ground MD: US Army Center for Health Promotion and Preventive Medicine, Publication 29-HE-2682-99, 1999.
32. Knapik, J. J., R. McCollam, M. Canham-Chervak, S. Arnold, E. L. Hoedebecke, and T. S. DuVernoy. *A Second Investigation of Injuries Among Officers Attending the US Army War College, Academic Year 2000.* Aberdeen Proving Ground: US Army Center for Health Promotion and Preventive Medicine, Publication No. 29-HE-2682-00, 2000.
33. Knapik, J. J. and M. A. Sharp. Task-specific and generalized physical training programs for improving manual material handling capability. *Int J Indust Ergon.* 22:149-160, 1998.
34. Knapik, J. J., M. A. Sharp, M. L. Canham, K. Hauret, J. Cuthie, W. Hewitson, E. Hoedebecke, M. J. Laurin, C. Polyak, D. Carroll, and B. Jones. *Injury incidence and injury risk factors among US Army Basic*

Trainees at Ft Jackson, SC (including fitness training unit personnel, discharges, and newstarts). Aberdeen Proving Ground MD: US Army Center for Health Promotion and Preventive Medicine, Publication 29-HE-8370-99, 1999.

35. Knapik, J. J., J. Wright, D. Kowal, and J. A. Vogel. The influence of U.S. Army Basic Initial Entry Training on the muscular strength of men and women. *Aviation Space and Environmental Medicine.* 51:1086-1090, 1980.
36. Kraus, B., J. Sinclair, and D. Castell. Distance running induces gastroesophageal reflux (GER). *Gastroenterol.* 96:A685, 1989.
37. Kujala, U. M., J. Kaprio, and S. Sarna. Osteoarthritis of weight bearing joints of the lower limbs in former elite male athletes. *BJM.* 308:231-234, 1994.
38. Kujala, U. M., J. Kettunen, H. Paananen, T. Aalto, M. C. Battie, O. Impivaara, and S. Sarna. Knee osteoarthritis in former runners, soccer players, weight lifters, and shooters. *Arthritis Rheum.* 38:539-546, 1995.
39. Laubach, L. L. Comparative muscular strength of men and women: a review of the literature. *Aviat Space Environ Med.* 47:534-542, 1976.
40. Lindberg, H. and F. Montgomery. Heavy labor and the occurrence of gonarthritis. *Clin Orthop.* 235:6-12, 1987.
41. Maetzel, A., M. Makela, G. Hawker, and C. Bombaedier. Osteoarthritis of the hip and knee and mechanical occupational exposure - a systematic overview of the evidence. *J Rheumatol.* 24:1599-1607, 1997.
42. McArdle, W. D., F. I. Katch, and V. L. Katch. *Exercise Physiology: Energy, Nutrition and Human Performance.* Philadelphia: Lea & Febiger, 1991
43. Nummela, A., H. Rusko, and A. Mero. EMG activities and ground reaction forces during fatigued and nonfatigued sprinting. *Med Sci Sports Exerc.* 26:605-609, 1994.
44. Peters, H. P. F., L. M. A. Akkermans, E. Bol, and W. L. Mosterd. Gastrointestinal symptoms during exercise. *Sports Med.* 20:65-76, 1995.
45. Peters, H. P. F., L. Seebregts, L. M. A. Akkermans, G. P. v. B. Hiengouwen, E. Bol, W. L. Mosterd, and W. R. d. Vries. Gastrointestinal symptoms in long distance runners, cyclists, and triathletes: prevalence, medication and etiology. *Am J Gastroenterol.* 94:1570-1576, 1999.
46. Raty, H. P., U. M. Kujala, T. Videman, O. Impivaara, M. C. Battie, and S. Sarna. Lifetime musculoskeletal symptoms and injuries among former elite male athletes. *Int J Sports Med.* 18:625-632, 1997.
47. Rehrer, N. J., G. M. E. Janssen, F. Brouns, and W. H. M. Saris. Fluid intake and gastrointestinal problems in runners competing in a 25-km race and marathon. *Int J Sports Med.* 10 (Suppl 1):S22-S25, 1989.
48. Riddoch, C. and T. Trinkick. Gastrointestinal disturbances in marathon runners. *Br J Sports Med.* 22:71-74, 1988.
49. Sandmark, H., C. Hogstedt, and E. Vingard. Primary osteoarthritis of the knee in men and women as a result of lifelong physical load from work. *Scand J Work Environ Health.* 26:20-25, 2000.

50. Schmidt-Truckasb, A., R. Reer, R. Eisele, and G. Herold. Gastrointestinal symptoms among runners and swimmers. *Int J Sports Med*. 17:S52, 1996.
51. Sprague, P. and R. V. Mann. The effects of muscular fatigue on the kinetics of sprint running. *Res Q Exerc Sport*. 54:60-66, 1983.
52. Sullivan, S. N. Exercise-associated symptoms in triathletes. *Physician Sportsmed*. 15(9):105-108, 1987.
53. Sullivan, S. N. The gastrointestinal symptoms of running. *New Engl J Med*. 304:915, 1984.
54. Worme, J. D., T. J. Doubt, A. Singh, C. J. Ryan, F. M. Moses, and P. A. Deuster. Dietary patterns, gastrointestinal complaints, and nutrition knowledge of recreational athletes. *Am J Clin Nutr*. 51:690-697, 1990.
55. Worobetz, L. J. and D. F. Gerrard. Gastrointestinal symptoms in Enduro athletes: prevalence and speculations on aetiology. *NZ Med J*. 98:644-646, 1985.

APPENDIX B

Biomechanical and Medical Considerations in Squatting Exercises

We conducted this literature review because of the concern over training for the power squat. If the power squat were an APRT test item this may encourage soldiers to perform an excessive number of repetitive knee bending exercises to achieve high scores. This review examines available evidence on the biomechanics of squatting and possible associations between repetitive squatting and injuries.

Biomechanical Considerations

Squatting can be defined as bending at the knees while supporting the body in an upright position. During this activity, the quadriceps and the patellar tendon pull (compress) the patella into the femoral condyles. This produces what is referred to as patellofemoral compressive forces (23). These forces have been shown to increase as the knee flexes, reach a maximal value at about 90-100° of knee flexion, and then remain relatively constant beyond 100° of knee flexion (17). In one study in which subjects performed squats with their 12 repetition maximum weight, compressive forces were <1500 N in the range of 0-50° of knee flexion but rose rapidly to about 4500 N at 80° of knee flexion (18). The only study found to estimate compressive forces during body weight squatting (i.e., similar to the power squat: no external load) estimated a force of 5455 N at 130° of knee flexion (15).

The amount of force per contact area (patella on femoral condyles) may be a more important indicator of patellofemoral stress than the total compressive forces. This is because a force spread over a larger area produces less pressure per unit area of contact. The contact area has been shown to progressively increase as the knee flexes. Contact pressures ranges have wide variations in different studies, probably due to different measurement techniques and assumptions. Despite this, studies show that contact pressures generally follow the same pattern as patellofemoral compressive forces (17, 24).

Other factors that may affect patellofemoral compressive forces on the knee during squatting include the position the feet are pointing (straight or angled) and the distance between the feet (stance width). Toe position does not appear to influence estimated patellofemoral compressive forces since there were no differences with the feet pointing straight ahead or pointing outward at a 30° angle (19). However, estimated compressive forces were greater with a wider stance than a narrower stance during the decent phase (19). Thus the narrow stance currently used for the power squat appears to be the appropriate one and there is no contraindication to the current foot position where the toes are pointed straight ahead.

Of lesser concern than patellofemoral compressive forces are the tibiofemoral shear and compressive forces generated by the muscle groups that cross the knee (quadriceps, hamstrings and gastrocnemius) during squatting. Shear forces appear to be well restrained by the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL). Estimated shear forces that are generated (even when subjects perform squatting with heavy loads) are well below the rupture strength of these ligaments (Table 7). Estimated peak tibiofemoral compressive forces range from 550 to 7928 N in different studies but it is not known if these forces have the potential to damage the menisci and/or articular cartilage. It should also be understood that tibiofemoral compressive forces are important for knee stabilization because they help resist shear and minimize movement of the femur on the tibia (17).

Table 7. Estimated Rupture Strength of Knee Ligaments and Estimated Peak Tibiofemoral Shear Forces (17)

	Estimated Rupture Strength (N)	Peak Anterior Tibiofemoral Shear Force (N)[a]	Peak Posterior Tibiofemoral Shear Force (N)[b]
Anterior Cruciate Ligament (ACL)	1725-2160	28-500	---
Posterior Cruciate Ligament (PCL)[c]	4000	----	29-2704

[a]ACL restrains anterior shear forces
[b]PCL restrains posterior shear forces
[c]The cross-sectional area of the PCL is 20% greater than the ACL accounting for greater strength

Injuries and Squatting

Tibiofemoral shear forces are unlikely to cause acute damage to ligaments (Table 7). However, it is possible that repetitive application of high tibiofemoral compressive forces might injure the menisci and/or tibial-femoral articular cartilages. It is also possible that high patellofemoral compressive forces repetitively applied may contribute to chondromalacia, osteoarthritis (17, 18, 23), and retropatellar pain. The knee is the site of the largest number of injuries in basic combat training (34), among active older soldiers (31, 32), and the knee is the site of the third largest number of injuries among infantry soldiers (30).

In order to examine the potential consequence of repetitive knee bending in the context of training for the power squat, the most appropriate studies would be of individuals who have been engaged in body weight squatting over a long period of time. However, no studies of this type were found in the literature. There were studies on osteoarthritis associated with occupationally related knee bending and competitive weight lifting. While these are not the most suitable for the present purposes, they do provide some indication of how repetitive knee bending may be associated with overuse injuries and they are reviewed below.

Two systematic reviews of the literature (27, 41) and two more recent studies (14, 49) examined the association between occupationally related knee bending and radiographically verified knee osteoarthritis. The studies generally showed that the odds of knee osteoarthritis was 1.4 to 6 times higher in men who did squatting or bending at work compared to men who had no or low exposure to squatting. However, many of these studies did not characterize well the squatting exposure or the type of squatting performed (continuous or intermittent). Some studies used occupational titles to determine squatting exposure (20, 40) and all individuals under a particular job title may not perform the same amount or type of squatting. One investigation that more carefully quantified exposure time found that men and women who squatted for more than 1 hour per day in total were at 2.3 times greater odds of osteoarthritis (95% CI=1.3-4.1) compared to matched controls even after controlling for body mass index, Heberden's nodes, and previous knee injury (14). The type of squatting (continuous or intermittent) may also be important and most studies do not collect this type of information. Squatting in one position for a long period of time may put point pressures on the menisci and/or articular cartilage while intermittent squatting may involve wider areas. One study (14) that attempted to examine intermittent squatting among older workers found little difference in osteoarthritis risk when squatting for 1 hour/day was compared to getting up from kneeling or squatting >30 times/day. However, many of the same individuals may have been in both groups and kneeling and squatting were confounded in the latter comparison.

Studies on weight lifters generally support the findings on the association between occupationally related knee bending and osteoarthritis. Two studies used the same group of subjects (38, 46) and examined knee osteoarthritis and knee pain in Finnish Olympic distance runners (n=28), soccer players (n=31), weight lifters (n=29) and shooters (n=29). Olympic weight lifting would require a great deal of squatting to train for both the snatch the clean and jerk. The age-adjusted odds of osteoarthritis were 13 times higher in the weight lifters compared to the shooters (95% CI=1.5-113). The age-adjusted risk of osteoarthritis increased with the number of years spent in kneeling or squatting exercise (OR=1.1/work year). The prevalence of knee pain at least once a month during the past year was higher in the weight lifters (31%) than in the shooters (17%) but this difference was not statistically significant, presumably because of the small sample size. In these studies the weight lifters also had high body mass index, which is a well-known risk factor for osteoarthritis (14, 41), and the investigators did not control for this. Also, weight lifting athletes would perform squatting under heavy loads, which may be different from body weight squatting used to train for the power squat.

Another investigation (37) examined 2448 male athletes who had represented Finland in Olympic, World, or European competitions and compared them to Finnish men who were healthy (fit for compulsive military service) at age 20 years. Hospital discharge records were compared between cases and controls for ICD-9 codes involving osteoarthritis of the hip, knees, and ankle. The age-adjusted odds of a weight-lifting athlete having osteoarthritis were 2.7 times higher than controls. The analysis was subsequently adjusted for age and

BMI, but weight lifters were grouped with boxers, wrestlers, and athletes involved in throwing sports. In this mixed group of athletes, the adjusted odds of osteoarthritis (controlling for age and BMI) were still 2.5 times higher than in controls.

In summary, the literature supports the concept that occupationally-related knee bending is associated with osteoarthritis. It also appears that weight lifters (athletes involved in exercises that require knee bending with heavy loads) are at greater risk of osteoarthritis. Although these groups are not the most appropriate ones to examine in the context of body weight squatting, they do suggest the possibility of osteoarthritis during repetitive knee bending for training. Further investigations should be conducted to examine the health consequence of repetitive knee bending in the context of a physical training program.

APPENDIX C

Review of the Literature on Vomiting and Nausea During Physical Activity

A small group of soldiers were observed to vomit and a larger number of soldiers said they had experienced nausea during the APRT. Because of this, we performed a review of the literature on vomiting and nausea that occures in conjunction with physical activity.

Quantitative reports in the literature of vomiting and nausea during exercise are shown in Table 8. All of the data in Table 8 were obtained on specific groups of triathletes, marathoners, and other sports involving similar activities. These activities differ considerably from the types of activities performed on the APRT since APRT events are all of a short term high intensity nature (with the exception of the 1-mile run). Thus, it is not possible to directly compare our incidence of vomiting to that of the literature.

All of the data in Table 8 were obtained by questionnaire. The proportion of questionnaire returned in most of the studies varied between 27% and 84% and it is possible that athletes with gastrointestinal (GI) problems would have been more likely to complete the questionnaires and thus elevate the symptom rates. In fact, the studies that did ask if subjects experienced GI problems outside the athletic event (26, 36, 45) found that athletes with resting GI complaints were more likely to experience complaints during activity.

Table 8. Prevelance of Nausea and Vomiting While Training for Various Sports

Reference	Training Activity/Sport	Exercise Intensity	Gender	Experiencing Symptoms (%)		
				Nausea or Vomiting	Nausea	Vomiting
29	Marathon	Hard			11.6	1.8
53	Running			6		
55	Triathlon with Canoe Portion				21	6
52	Triathletes					
48	Marathon	Hard	Men		25	16
54	Triathletes				6	
26	Marathon			6		

Risk factors for nausea and/or vomiting include 1) strenuous exercise, 2) eating or drinking in close proximity to the activity, and 3) female gender. A number of studies have documented that nausea and vomiting are much more common in strenuous exercise compared to milder exercise but in all of these studies the definition of "strenuous exercise" is self-reported (26, 29, 48, 50, 52, 55). The incidence of nausea, vomiting, and other upper GI complaints are higher when individuals eat or drink prior to or during exercise (45, 52, 55). Women experience more nausea than men (29, 45). Studies on the association of age and GI upsets are conflicting (26, 45, 55).

The etiology of nausea and vomiting during exercise is much more difficult to discern but delayed gastric emptying, dehydration, redirection of blood flow from the splanchnic vascular bed to the active muscles, and mechanical stess may be associated with the phenomona. High intensity exercise (>70% VO2max) tends to delay gastric emptying (11) and this may be associated with GI symptoms. Dehydration involving a loss of >4% of body weight has also been shown to increase GI disturbances (47). During exercise, the splanchnic vascular beds vasoconstrict and blood flow is shunted to the working muscles and skin (for thermoregulation). The decrease in splanchnic blood flow is inversely proportional to exercise intensity, exercise duration, and the ambient heat (25, 44). One study found that superior mesenteric blood flow was reduced by 80% in a symptomatic runner but there was little change in mesenteric blood flow in an asymptomatic runner (Kehl et al., cited in 44) suggesting the magnitude of the blood flow reduction in particular individuals may be associated with GI symptoms.

Mechanical stress due to the "pounding" or "jarring" effects of exercise have been suggested as a possible mechanism of GI upsets (44). This hypothesis is supported by studies of triathletes and other situations involving multiple activities that show a greater frequency of nausea, vomiting, and gastroesophageal reflux during the running compared with activities that cause less mechanical stress like cycling and swimming (13, 36, 52). In running, the foot strikes the ground with a force two to three times body weight (12, 16, 21) and repeated cycles could directly effect effect intestinal cells, cause contractions of the abdomen or diaphragm, or effect neuropeptide release (44).

APPENDIX D

Acknowledgements

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