



Physical Readiness Training: A Meta-Analysis

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Summary

Background

Physical training is essential for military personnel. Training enhances physical readiness, the physical capacity to perform essential military tasks. However, training can cause injuries that impair performance. Recent advances in training methods may provide better control over the tradeoff between fitness gains and injury. The U.S. Army has developed physical readiness training (PRT) as a conceptual approach to this problem. PRT-based training programs have been evaluated in three studies to date.

Objective

This review integrates the findings from available studies to provide quantitative estimates of PRT effects on fitness and injury.

Methods

PRT programs have been evaluated twice in basic combat training and once in Advanced Individual Training. Training programs lasted 7 to 9 weeks. Summary statistics describing the program effects were extracted from journal articles and technical reports. Fitness outcomes were the sit-up, push-up, and run tests that make up the Army Physical Fitness Test (APFT). Medical outcomes were overuse injuries and traumatic injuries. Meta-analyses for fitness outcomes were conducted using the means and standard deviations for the APFT measures as the input data. Meta-analysis of injury outcomes were conducted using the injury hazard ratios from Cox regressions with covariates as the input data. Results for men and women were considered separately, so the meta-analyses involved six estimates for the program effect on each outcome.

Results

APFT gains in the PRT program equaled those in the traditional program. The traditional program produced more overuse injuries in all comparisons. The pooled hazard rates for overuse injuries and traumatic injuries in the traditional program were 48% and 24% higher, respectively. In this case, a positive PRT effect was evident in only 3 of 6 samples. Using a one-tailed significance test that assumed that PRT would reduce injuries, the pooled hazard ratio was significant for overuse injuries ($p < .001$, 1-tailed) and traumatic injuries ($p < .032$, 1-tailed). Gender differences in PRT effects were nearly nonexistent and did not approach statistical significance.

Discussion

The PRT program reduced injury rates without affecting fitness gains. The available evidence is sufficient to justify using the PRT approach to reduce injuries in formal, structured training settings. The results should be cautiously extrapolated to other settings. Guidelines for implementing the PRT approach and evaluating its effects could be refined with further study.

Many military missions are physically demanding. The importance of having each combatant able to meet mission demands has increased as military strategy moves toward distributed operations (Record, 1988, cited in Amos, 2007). Military personnel must be able to perform a wide range of physical tasks if they are to meet the dynamic needs arising on the battlefield. The combatant becomes a warrior athlete whose physical superiority complements skill training. Combining skills with the physical capacity to apply those skills is the key to dominance on a battlefield that consists of scattered micro-engagements with small contingents of enemy combatants.

Distributed operations accentuate the importance of physical fitness. Tracing this keynote back, conceptual models of combat requirements in distributed operations underscore the traditional emphasis on the importance of physical training. At the same time, the concepts that are central to distributed operations suggest the need for re-evaluating specific emphases that have been characteristic of traditional physical training programs. The goal of military physical training is to provide the performance capabilities required for battlefield success. Traditional physical training programs have focused on aerobic endurance because this capacity is a required element of military physical fitness tests (Department of Defense, 2004). The combat tasks anticipated in distributed operations suggest the need for increased emphasis on other capabilities, including anaerobic power, balance, and flexibility. The current view is clearly stated in the U.S. Marine Corps document “A Concept for Functional Fitness” (Amos, 2006, p. 2):

The need for balanced development of a range of capabilities is the central idea behind functional fitness or combat conditioning concept of physical training for Marines. Current orders and doctrine may not optimally support a complete fitness program that follows combat function. The program over-emphasizes aerobic training (long distance running) and gives very little attention to strength training. Combat demands a fitness that follows function, based on core strength and total body stamina. An unsophisticated exercise routine based almost entirely on mono-structural metabolic conditioning cannot provide the sort of training stimulus necessary to build General Physical Preparedness (GPP). Further, the current program, unlike sports programs, places little attention on “injury-proofing” Marines or on training around an injury during “active recovery.

Any physical training program involves physical exertion as a stimulus for physiological adaptations that improve fitness. Exertion necessarily involves some risk of injury. To optimize combat readiness, physical fitness programs must be properly focused, graduated, and structured to enhance the specific physical capabilities required for combat success. Programs with these characteristics will achieve this objective while minimizing injuries. The modern approach to combat conditioning must address the tradeoff between stimulating improvements in fitness and minimizing injury while presenting trainees with the broad range of physical challenges needed to develop the range of capabilities that are critical to distributed operations. The increased breadth in physical challenges needed to produce the desired range of fitness gains increases the

complexity of the problems that must be solved to design physical training programs that are safe and effective.

Faced with similar needs, the U.S. Army developed a physical readiness training (PRT) program (Knapik, Hauret, et al., 2001). The conceptual framework for the program is:

1. Physical fitness refers to the ability to carry out daily tasks. Muscular strength, muscular endurance, and cardiorespiratory endurance are the major components of fitness.
2. Physical readiness in the military is the capacity to meet duty demands at a level that accomplishes the mission without reaching the point of exhaustion (i.e., with physical reserves). Each element of physical fitness is required and must be applied effectively to military tasks.
3. The components of physical readiness are strength, endurance, and mobility.

These principles make the important point that physical fitness is a means to an end in the military. Fitness contributes to physical readiness. Physical readiness is expressed in the demonstration of abilities that contribute to high levels of performance of combat tasks. Performance on those tasks links readiness to increased likelihood of mission success. The conceptual framework provides an explicit link between fitness, training, and the ultimate training goal—mission success.

The PRT program is designed to promote readiness. The program rests on the principles of progression, variety, and precision:

1. Progression is the gradual increase in total amount of exercise performed. The total can be increased by manipulating the frequency, duration, and intensity of the exercise.
2. Variety is achieved by including different types of training within a program. The types of training should be selected to target each of the major components of physical fitness.
3. Precision focuses on ensuring that exercises are performed properly to train the intended muscle groups and establish proper movement patterns. The program emphasizes proper form (i.e., posture and movement pattern) to achieve this end.

The principles that guide the design of the actual content of PRT programs imply a subtle shift in the training target relative to traditional training methods. The emphases on variety and form suggest greater attention to linking training to task requirements. This shift is captured in the use of the term “physical readiness training” as the overarching conceptual approach.

The PRT approach is expected to improve readiness while reducing injuries. The connection to reduced injury rates is not explicit in the concepts or principles. However, factors that contribute to injury rates were key elements in developing the conceptual approach (Knapik, Hauret, et al., 2001). Three studies have systematically evaluated the effects of applying this approach in military training. Each study compared the PRT

approach to traditional military physical training. The comparisons considered changes in physical fitness and injury rates. This paper provides a quantitative summary of those studies.

Table 1. Sample Size and Age of Experimental and Control Groups

	Experimental Group			Control Group			Sig.
	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	
AIT							
Men	1122	19.8	2.8	161	20.4	3.3	<.01
Women	2303	20.1	3.3	256	20.4	3.2	.48
BCT 1							
Men	759	20.9	3.4	630	20.7	3.3	.13
Women	505	20.9	3.7	637	20.7	3.4	.09
BCT 2							
Men	486	21.9	3.8	656	21.9	4.1	.98
Women	343	21.9	4.3	482	21.4	4.0	.08

Note. AIT = advanced individual training; BCT 1 and 2 = basic combat training, studies 1 and 2.

Methods

Literature

The U.S. Army has conducted three major studies of the PRT program. Two studies were conducted in military basic combat training (BCT; Knapik, Hauret, et al., 2003; Knapik, Dahakjy, et al., 2005). In this paper, these studies are labeled BCT1 and BCT2, respectively. The third study was conducted in Advanced Individual Training (AIT; Knapik, Bullock et al., 2004). Additional detail on the physical training programs can be found in technical reports available from the Defense Technical Information Center (Knapik, Hauret, et al., 2001; Knapik, Bullock, et al., 2003; Knapik, Dahakjy et al., 2004).

Samples

Table 1 gives the size, age, and gender composition for the sample in each study. The samples were sufficiently similar in age to be comparable for practical purposes. This statement is defensible even though age differed significantly in some comparisons of the experimental and control groups. As Rosenthal and Rosnow (1984) noted, “Significance Test = Size of Effect X Size of Study.” This conceptual definition of significance tests is a reminder that even minor differences will be statistically significant given large enough samples. To guard against mistaking large sample size for a truly important difference, Cohen (1988) suggested that any effect that is less than 0.2 standard deviations is too small to be of theoretical or practical importance. The standard deviation of the control group can be used to compute effect size (ES). Adopting this approach, none of the differences in Table 1 meet Cohen’s minimum standard for an important effect. This statement includes those differences that are statistically significant (AIT men, ES = .18; BCT1 women, ES = .06; BCT 2 women, ES = .13). Thus, the statistical significance of

these differences clearly is a function of the large size of the samples involved rather than a meaningful difference between the experimental and control groups.¹

Training Programs

The traditional physical training program for the study populations involved warm-up, stretching, calisthenics, variations on push-ups and sit-ups, and formation running. Formation running split trainees into four ability groups.

The PRT program consisted of six different types of exercises: calisthenics, dumbbell drills, movement drills, interval training, long-distance running, and flexibility training. The PRT program emphasized the correct selection of initial training intensities and carefully controlled increases in training intensity during the program. The PRT program also employed ability groupings for the long-distance runs that were the endurance training element of the program. Details of the specific exercises, methods of setting the initial intensity levels, and schedules for increasing intensity during PRT program training can be found in the articles and technical reports previously cited. The technical reports include illustrations of specific exercise procedures.

Program duration was comparable in each study. BCT lasts 9 weeks. AIT lasts 8 weeks. However, in BCT2, the PRT program stopped after the seventh week. The PRT program was replaced by 2 weeks of exercise procedures that focused on training for specific elements of the standard U.S. Army Physical Fitness Test (Knapik, Dahakjy, et al., 2005). The shift was introduced to improve push-up performance after BCT1 showed a deficit in this element of the final fitness test. As a result, the PRT program lasted 7 weeks (BCT2), 8 weeks (AIT), or 9 weeks (BCT1).

Study Designs

The PRT program evaluations employed two study designs. The BCT studies compared recruits completing the new training program with concurrent samples of recruits completing the traditional program. The AIT study compared trainees participating in the PRT program with a historical cohort. In each case, unit membership determined assignment to a training program. Trainees were not individually randomized to treatment conditions.

Physical Fitness Measures

The fitness measures were APFT components: push-ups, sit-ups, and a 2-mi run. Push-up performance is the number of push-ups completed in 2 min. Sit-up performance is the number of sit-ups completed in 2 min. The 2-mi run performance is the time required to complete the run.

¹Each study examined additional characteristics. The specifics of the comparisons varied from study to study. The trend was the same in all cases. Differences either were not significant or represented small effects. The age comparisons in Table 1 were representative of the general trend.

Fitness measures were recorded at the beginning and end of each study. The standard APFT was administered for 5 of the 6 testing sessions. A modified APFT was administered at the beginning of BCT2. The modified test provided a diagnostic evaluation of initial fitness based on 1-min tests for push-ups and sit-ups and a 1-mi run.

Injury Effects

Injury rates were determined from medical records. Injuries were classified on the basis of two characteristics. *Injury type* distinguished overuse injuries from traumatic injuries. Knapik, Hauret, et al. (2003, p. 374) defined these categories as follows:

Overuse injuries were presumably due to long-term energy exchanges resulting in cumulative microtrauma and included stress fractures, stress reactions, tendonitis, bursitis, fasciitis overuse syndromes, strains, and musculoskeletal pain (not otherwise specified). Traumatic injuries were presumably due to sudden energy exchanges resulting in abrupt tissue overload and included sprains, dislocations, fractures, blisters, abrasions, lacerations, contusions, and pain (due to an acute event).

The second characteristic, *injury severity*, distinguished injuries that resulted in duty restrictions (i.e., time-loss injuries) from less severe injuries. This review only considers time-loss injuries. Injuries that do not lead to duty restrictions arguably have little or no effect on readiness.

Data Coding

Data coding extracted summary statistics to characterize program effects. The means and standard deviations were extracted for APFT tests. APFT scores were coded for tests administered at the beginning of training and at the end of training.

The hazard ratio (HR) from Cox proportional hazards regression, a survival analysis procedure, was the index of injury effects. HR is based on the distribution of injuries over time within the two groups (cf., Hosmer & Lemeshow, 1999). Because the PRT program was the reference group in all of the analyses, $HR > 1$ indicates that the PRT program reduced the injury rate, and $HR < 1$ indicates that the PRT program increased the injury rate. If $HR = 1$, the PRT injury rate was equal to the rate in the traditional program.

The meta-analysis used HR values from multivariate Cox regression analyses. These analyses included trainee attributes as covariates. The covariates provided statistical adjustments to allow for differences in the composition of the study groups. These adjustments were introduced into the analysis model to minimize the likelihood that the analyses would provide biased estimates of program effects. Bias would occur if the experimental and control groups differed on some attribute that affects the injury rate (James, Mulaik, & Brett, 1982).²

²Knapik and colleagues also reported ratios derived without controls for potential confounding variables. The HR values from those univariate analyses were very similar to the HR values from the multivariate

The HR values provided by the technical reports have been analyzed rather than the HR values in the published papers. Each technical report included HR values for overuse injuries, traumatic injuries, and overall injuries. The published papers sometimes omitted one or more of these values. Basing the analyses on the technical reports increased the number of samples available to estimate each pooled HR.³

Analysis Procedures

The meta-analysis followed the general procedures outlined by Hedges and Olkin (1985). The computations for APFT tests were:

1. Compute the mean difference between the experimental and control group ($E - C$).
2. Compute the pooled standard deviation for the two groups.
3. Compute Cohen's d ($[E - C]/\text{Pooled SD}$).
4. Complete steps 1 through 3 for the initial and final APFTs to obtain initial d and final d .
5. Compute an adjusted d for the end of training (Adjusted $d = \text{final } d - \text{initial } d$).
6. Convert the adjusted d to a correlation coefficient, $r = d/\sqrt{d^2 + 4}$.
7. Apply Fisher's r -to- Z transformation to obtain a Z statistic that is approximately normally distributed with a known variance of $1/(N - 3)$ where N is the combined sample size for the experimental and control groups.
8. Use the SPSS software (version 12, SPSS, Inc., Chicago, IL) GLM routine to conduct a weighted analysis of the PRT effects. The inverse of the variance (i.e., $N - 3$) is the weight factor.
9. Reverse the Fisher's r -to- Z transformation to convert the weighted pooled Z values to pooled correlations.⁴

The HR meta-analysis was based on three statistics taken from the technical reports: the HR controlling for covariates, the upper bound of the 95% confidence interval (CI) for the HR, and the lower bound of the 95% CI for the HR. After extracting the data, the analysis steps were:

1. Take the natural logarithm ($\ln$) of each HR.
2. Compute the standard deviation for HR, $(\ln[\text{HR upper bound}] - \ln[\text{HR lower bound}])/3.92$ (cf., Parmar, Torri & Stewart, 1998, p. 2819, Equation 7).⁵
3. Square the standard deviation to estimate the HR variance.
4. Take the inverse of the HR variance to obtain a weight for the HR analyses.

analyses. The multivariate HR values were used to provide a consistent method that protected against any identifiable confounding in the data.

³Some HR values in the technical reports differed slightly from the published values. The differences were small; analyses conducted with the published values in place of the technical report values did not affect the conclusions from this meta-analysis.

⁴The analyses did not include Hedges and Olkin's (1985) corrections for bias in the correlation coefficient. The correction has its greatest impact when the ES for a small sample is large. The present analyses involved ES values for large samples. The correction would have been too small to be important.

⁵See Appendix A for HR values used in these computations.

5. Apply GLM with the inverse variance weights to estimate the pooled $\ln(\text{HR})$.
6. Compute the standard deviation for the pooled $\ln(\text{HR})$ by taking the square root of the inverse of the summed HR weights.
7. Use the standard deviation to compute the 95% CI pooled $\ln(\text{HR})$ by standard methods.
8. Compute the exponentials of the pooled $\ln(\text{HR})$, the lower bound of the 95% CI, and the upper bound of the 95% CI to obtain the pooled HR and the boundaries for the 95% CI of this estimate.

Other analysis details needed to interpret the findings are presented in the *Results* section.

Results

Fitness Effects

The programs produced equivalent fitness outcomes. Except in rare cases, $r = .10$ (absolute) is the minimum ES that would indicate practical or theoretical significance (Cohen, 1988). Every pooled correlation in Table 2 was less than half this minimum. When studies were considered individually, the PRT program had a negative effect on push-up scores in BCT1 for both men and women.

The pooled effects may be misleading. The effects varied significantly across samples. The GLM results indicated the following:

- Overall, ES varied significantly for push-ups ($\chi^2 = 70.67, 5 \text{ df}, p < .001$), sit-ups ($\chi^2 = 17.54, 5 \text{ df}, p < .004$), and run test ($\chi^2 = 12.76, 5 \text{ df}, p < .026$).
- Gender was related to ES for push-ups ($\chi^2 = 14.08, 1 \text{ df}, p < .001$) and sit-ups ($\chi^2 = 5.63, 1 \text{ df}, p < .018$), but not for run time ($\chi^2 = 3.29, 1 \text{ df}, p > .069$).

Sample size explained most of the significant variation. Applying Rosenthal & Rosnow's (1984) conceptual equation, Significance Test = Size of Effect X Size of Study, the χ^2 is ES multiplied by the sample size. The large sample sizes in these analyses ($N \geq 825$, cf., Table 1) may be amplifying minor variations in ES.

Hoelter (1983) suggested that models have acceptable fit to the data if χ^2 is not significant when $N = 200$ in each group. Repeating the analyses with $N = 200$ for each group, the ES variation for push-ups was statistically significant ($\chi^2 = 24.49, 5 \text{ df}, p < .001$). In this modified analysis, ES did not vary significantly for sit-ups ($\chi^2 = 6.30, 5 \text{ df}, p > .278$) or the run test χ^2 ($\chi^2 = 2.74, 5 \text{ df}, p > .739$). Gender differences were not significant (push-ups, $\chi^2 = 0.99, 1 \text{ df}, p > .319$; sit-ups, $\chi^2 = 2.76, 1 \text{ df}, p > .096$; run test, $\chi^2 = 0.20, 1 \text{ df}, p > .654$).

Table 2. Combat Conditioning Program Effects on Fitness Indices

	Point-Biserial Correlation:		
	Push-ups	Sit-Ups	Run Test
BCT2 Male	.01	.02	.03*
BCT2 Female	.00	-.01	.00
BCT1 Male	-.12***	-.06*	-.04
BCT1 Female	-.25***	.08**	-.05
AIT Male	.00	-.04	-.04
AIT Female	.03	.04	-.06
Pooled	-.04	.01	-.01

Note. BCT = basic combat training, studies 1 and 2; AIT = advanced individual training. A positive correlation indicates better performance in the PRT program; a negative correlation indicates better performance in the traditional program.

* $p < .05$. ** $p < .01$. *** $p < .001$.

The negative effect of the PRT program in BCT1 was the basis for the significant variation in push-up effects. Study differences accounted for much of the variation in push-up effects ($\chi^2 = 59.43$, 2 *df*, $p < .001$). The residual variation was significant ($\chi^2 = 11.23$, 3 *df*, $p < .011$). The difference in ES for men and women in BCT1 was the primary factor in the residual variation ($\chi^2 = 10.59$, 1 *df*, $p < .001$). Gender differences were trivial in BCT2 and AIT ($\chi^2 = 0.64$, 2 *df*, $p > .726$).

The results of these analyses form a simple picture. With one exception, the training programs produced equivalent fitness gains. The negative effect of the PRT program on push-up performance in BCT1 was the exception. This negative effect was stronger for women than for men, but small in both cases.

Injury Effects

The PRT program reduced the rate of overuse injuries. Figure 1 presents the HR value for overuse injury computed for each of the six samples in the three studies. The pooled estimate at the top of the figure represents the combined results from the six samples. The 95% CI is shown for the individual estimates and the pooled estimate. Narrow intervals indicate less uncertainty about the true HR value. The broken line indicates what HR would be if survival times were equal in the two training programs. HRs to the left of the broken indicate longer survival times in the traditional program. HRs to the right of the line indicate longer survival times in the PRT program.

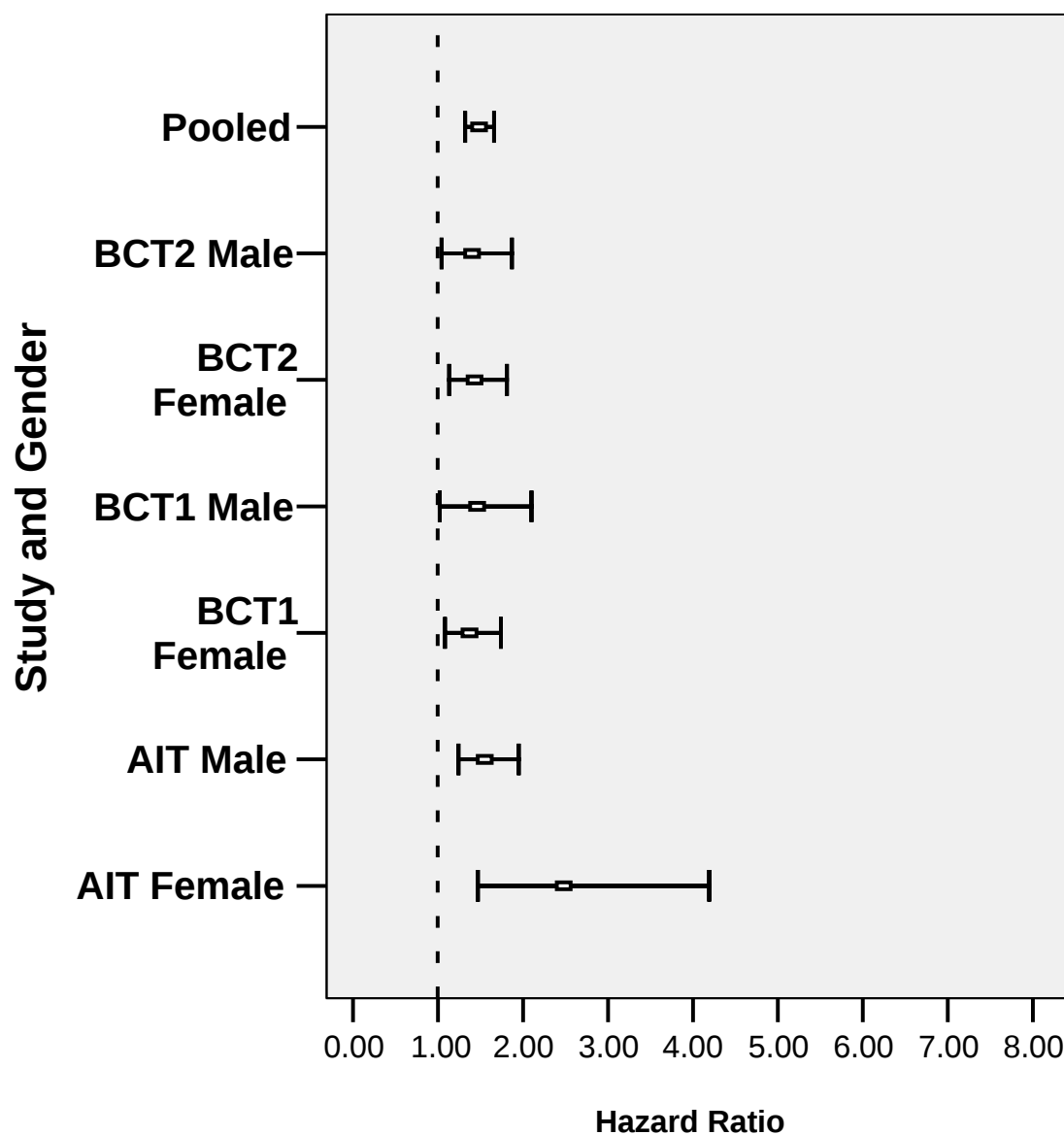


Figure 1. Effect of Training Program on Overuse Injury Rates.

Note. BCT = basic combat training, studies 1 and 2; AIT = advanced individual training. The dashed line indicates an equal hazard rate for both programs. Values to the right of the line indicate a higher rate in the traditional program.

Table 3. Hazard Ratios for Time-Loss Injuries by Injury Type and Gender

Injury Type	Gender	95% Confidence Interval			z	Sig. ^a
		Hazard Ratio	Lower Bound	Upper Bound		
Overuse						
	Female	1.48	1.26	1.73	4.76	.001
	Male	1.49	1.27	1.74	4.86	.001
	Combined	1.48	1.32	1.66	6.80	.001
Trauma						
	Female	1.24	.94	1.64	1.54	.124
	Male	1.23	.85	1.80	1.09	.276
	Combined	1.24	.99	1.55	1.87	.062
Any						
	Female	1.39	1.20	1.60	4.44	.001
	Male	1.44	1.26	1.65	5.31	.001
	Combined	1.42	1.28	1.56	6.91	.001

Note. Table entries are pooled values for the 3 studies using inverse variance weights (see text for details). The hazard ratios are the reported multivariate ratios with controls for covariates. The confidence intervals are based on the pooled variance estimate.

^a2-tailed.

Survival times for overuse injury consistently were longer in the PRT program (Figure 1). All six HRs exceeded 1.00. None of the CIs included the line indicating equal hazards in both programs. Because the variation in HRs was no greater than expected by chance ($\chi^2 = 4.52$, 5 *df*, $p > .477$), the pooled estimate, HR = 1.48, applied to all six samples. The hypothesis that survival times were equal in the 2 programs was rejected ($z = 6.80$, $p < .001$).

The results for traumatic injury were more ambiguous (Figure 2). Half of the HRs favored the PRT program. The two statistically significantly ($p > .05$, 2-tailed) HRs favored the PRT program.⁶ HR variation was not significant ($\chi^2 = 8.76$, 5 *df*, $p > .118$), so the pooled value, HR = 1.24, is representative of the set. The lower bound of the 95% CI was 0.99, so HR = 1.00 was within the range of plausible values. However, the pooled value was significant ($z = 1.87$, $p = .031$, 1-tailed) given the expectation that the PRT program would reduce injury rates.

Table 3 provides a slightly different look at the injury evidence. Separate summary HR values are given for men and women. Table 3 also provides the pooled

⁶ A 2-tailed significance test is appropriate for these ratios because the effect was not in the predicted direction. Effects in both directions must be considered to conduct a significance test for these ratios.

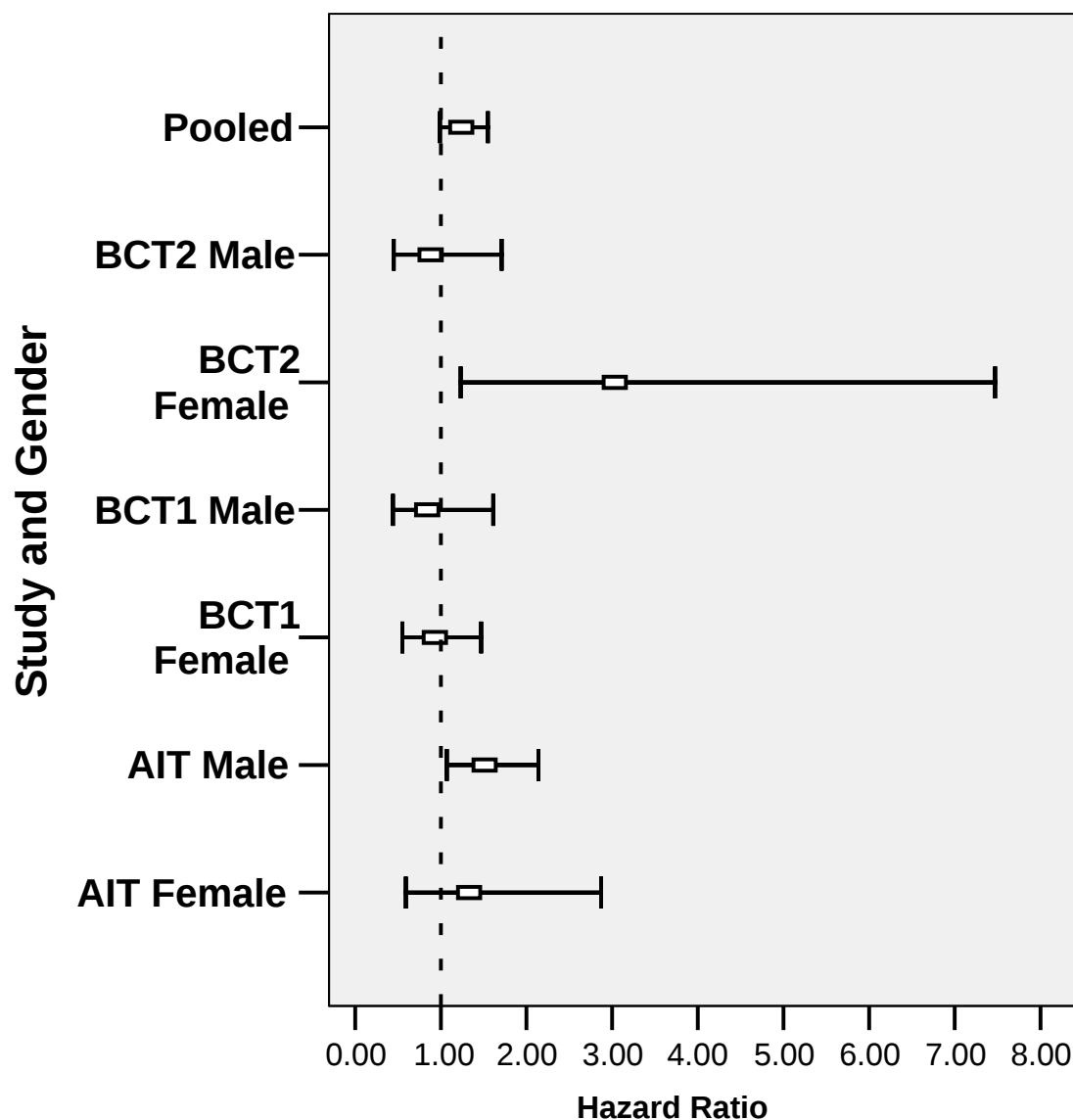


Figure 2. Effect of Training Program on Traumatic Injury Rates.

Note. BCT = basic combat training, studies 1 and 2; AIT = advanced individual training. The dashed line indicates an equal hazard rate for both programs. Values to the left of the line indicate a higher rate in the PRT program. Values to the right of the line indicate a higher rate in the traditional program.

estimates for PRT effects with overuse and traumatic injury combined. Statistical tests indicated that:

- Gender did not affect HR (overuse, $\chi^2 = .003$, 1 *df*, $p > .956$; traumatic, $\chi^2 = .001$, 1 *df*, $p > .974$; any, $\chi^2 = .15$, 1 *df*, $p > .701$).
- Injury type did not affect HR ($\chi^2 = 1.85$, 1 *df*, $p > .173$). However, the HR for overuse injuries was higher than the HR for traumatic injuries in 5 of 6 samples. The consistency of this trend approached significance ($p < .11$).
- The overall variation in HR was not significant ($\chi^2 = 15.24$, 11 *df*, $p > .171$). The PRT program may have the same effect on both types of injury.
- The cumulative pooled HR for “Any” injury was HR = 1.42.

Discussion

The PRT approach reduces injury rates. The pooled hazard rates for overuse injuries and traumatic injuries in the traditional program were 48% and 24% higher, respectively.⁷ Both effects are statistically significant given the initial hypothesis that application of PRT principles would reduce injury rates. This assumption is reasonable given that injury reduction was considered when developing the program principles and design (Knapik, Hauret, et al., 2001).

Injury reduction is achieved without sacrificing fitness gains. Both the PRT program and traditional training program improve APFT scores. The fitness gains are the same for both programs, although the PRT push-up gains were slightly smaller in BCT1. The importance of this finding is uncertain because it has not been replicated. Whether the difference would have replicated in BCT2 is unknown. The PRT program was modified on the assumption that the result would replicate. The modified program produced push-up performance equal to that in the traditional program. The difference in push-up outcomes for BCT1 and BCT2 may mean that the BCT2 modification was necessary. However, the possibility that the same result would have been obtained without the modification cannot be ruled out. The generality of any effect of the PRT program on push-up performance would be questionable in either case. No difference in push-up performance was evident in the AIT study. If an adverse PRT effect on push-up performance exists, the effect may be limited to entry-level military fitness training.

The PRT program has a stronger effect on overuse injuries than on traumatic injuries. This trend was consistent across samples even though it was not statistically significant. Physical training can be viewed as controlled induction of microtrauma. Fitness gains are the body's adaptation to this controlled physiological challenge. Careful titration of the trauma may be the key to avoiding overuse injuries because cumulative microtrauma is the central causal factor for these injuries. Physical training may be one of a number of

⁷The effect could also be characterized as showing that the PRT approach reduced overuse injury rates by 32% and traumatic injury rates by 19%.

training activities that increase the risk of accidents that lead to trauma. The PRT focus on the causative agent for overuse injuries, coupled with the consistent trend in the differences is reason to believe the difference in effects should be considered when evaluating PRT program effects.

All studies have limitations. The primary studies imposed limitations on the statistical procedures. Variance estimates were only approximations. Any resulting inaccuracies affect the weights used to pool HR values and compute CIs. Parmar et al. (1998) provide a method for estimating accuracy. The z scores based on their variance estimate are compared with z scores corresponding to significance levels reported in the original studies. The 10 comparisons that could be made in this case indicated accurate estimation of the variance. The estimated standard deviations were within 3% in 8 of 10 cases. The remaining cases involved $HR \approx 1.00$, so the accuracy of the method may be limited when effects are negligible. On the whole, there is little reason to believe that relying on approximate weights significantly affected the findings.

The available evidence leaves some important issues unresolved. Does the PRT approach reduce overuse injuries more than it reduces traumatic injuries? Plausible arguments and trends in the available evidence point to an affirmative answer to this question. The evidence is not yet strong enough to be sure that these points are valid.

Have the PRT effects on fitness been characterized adequately? The APFT measures aerobic endurance and upper body muscle endurance. The programs that would be envisioned to support distributed operations and the PRT approach to fitness consider a wider range of physical abilities. For example, the PRT approach should promote flexibility, balance, and lower body power. If the PRT approach is superior to the traditional program in developing these capabilities, the difference cannot be demonstrated using the APFT. Unmeasured benefits are invisible.

What are the key elements of the PRT approach? The PRT approach consists of several principles. The PRT implementations have combined these principles with other approaches to injury reduction. Knapik, Bullock, et al. (2003) made this point when they referred to the “multiple intervention” character of the program they studied. The complexity of the interventions makes it impossible to tell whether some PRT principles are more important than others. It is not even possible to determine whether the PRT approach will reduce injuries if it is not implemented as part of a general injury control program.

Will the PRT effects generalize across training settings? The available evidence comes from highly controlled training environments. PRT programs can be expected to have greater variability in content and implementation in less structured settings. The selection of elements and rates of progression in exercise intensity can be expected to differ. The differences may lead to much different effects than observed to date. Also, all studies to date involved personnel near the beginning of their military career. It is not certain that the PRT effects seen here will generalize to populations that are more fit at the beginning of the program. Entry-level fitness gains are most pronounced in relatively unfit trainees

(Trank, Ryman, Minagawa, Trone, & Shaffer, 2001). These individuals are at greater risk for injuries (Jones & Knapik, 1999). The greater level of fitness at the end of initial training experiences could reduce the impact of the PRT approach in later training.

The application of PRT principles offers a safe method of enhancing physical readiness for distributed operations. Properly designed and controlled physical training programs based on PRT principles can be expected to reduce injury rates without impairing readiness. These conclusions are subject to potentially important caveats. The conclusions may be appropriate only for highly structured entry-level training. The PRT approach may have to be implemented as part of a larger injury control program to ensure the injury reduction effects. The impact on readiness is uncertain because PRT effects on potentially important physical abilities have not yet been determined. The evidence from small set of studies now available provides strong encouragement to pursue these issues.

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Appendix A. Adjusted Hazard Ratios from Multivariate Cox Regression Models

Injury Type	Gender	Study	95% Confidence Interval		
			Hazard Ratio	Lower Bound	Upper Bound
Overuse	Males	BCT1	1.46	1.02	2.10
		BCT2	1.40	1.04	1.87
		AIT	1.55	1.24	1.95
	Females	BCT1	1.37	1.08	1.74
		BCT2	1.43	1.13	1.81
		AIT	2.48	1.47	4.19
	Males	BCT1	.84	.44	1.61
		BCT2	.88	.45	1.71
		AIT	1.51	1.07	2.14
Trauma	Females	BCT1	.93	.55	1.47
		BCT2	3.03	1.23	7.47
		AIT	1.33	.59	2.87
Total	Males	BCT1	1.23	.89	1.69
		BCT2	1.55	1.21	1.98
		AIT	1.46	1.21	1.76
	Females	BCT1	1.27	1.02	1.57
		BCT2	1.47	1.18	1.82
		AIT	1.58	1.01	2.45

Note. Statistics were extracted from the technical reports describing the PRT program evaluations: BCT1 = Knapik, Hauret, et al., 2001; BCT2 = Knapik, Dahakjy, et al., 2004; AIT = Knapik, Bullock, et al., 2003.

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14. ABSTRACT (maximum 200 words)

Distributed operations accentuate the need for physical fitness in military personnel. Traditional training practices may not be aligned with the fitness requirements of DO combat. Physical readiness training (PRT) is a conceptual approach to address this problem. PRT programs are designed to develop the required fitness gains while minimizing injuries rates. This meta-analysis of available PRT studies ($k = 3$) indicated that (a) Fitness gains in the PRT program were equal to the gains in traditional fitness programs, and (b) the injury rate (i.e., hazard ratio) for the traditional fitness program was 42% higher for overuse injuries and 24% higher for traumatic injuries. The studies took place in highly structured training settings, with push-ups, sit-ups, and 2-mi run times as fitness measures. The encouraging initial results support applying PRT principles in entry-level training. The PRT principles logically apply to physical training in other settings, but the generality of the effects needs to be confirmed. Also, some of the physical capabilities targeted in the PRT approach have not been measured in past studies, so PRT fitness effects may be underestimated.

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operational readiness, physical training, meta-analysis, injury, physical fitness

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