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Original Research

Acute Effects of Post-activation Performance Enhancement Exercises on Army Combat Fitness Test Performance in Male ROTC Cadets

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ABSTRACT

International Journal of Exercise Science 17(4): 154-171, 2024. The purpose of this study was to evaluate the effectiveness of implementing task-specific, post-activation performance enhancement (PAPE) strategies, to acutely improve Army Combat Fitness Test (ACFT) performance. Nineteen ROTC cadets completed two ACFTs, separated by 72 hours. Approximately half (n = 10) completed the traditional "Preparation Drill" as their warm-up prior to the first session and added PAPE warm-up strategies as part of their second session. The other group (n = 9) completed the treatments in the opposite order to facilitate a repeated-measures, crossover design. The participants' composite ACFT score was used as the primary outcome measure of interest to explore mean difference in a two-way (Time x Treatment), repeated measures ANOVA. There was no interaction [$F(1,8) = 0.075$, $p = 0.79$] nor main effect of treatment [$F(1,8) = 0.084$, $p = 0.78$]. However, there was a main effect of Time [$F(1,8) = 58.87$, $p < 0.001$, $d = 0.25$] (mean ACFT score ± SD: Session 1 = 527 ± 43, Session 2 = 537 ± 39). The results of this study did not support the use of additional PAPE strategies to improve ACFT performance. However, there was a practice effect when the test was completed twice, separated by 72 hours in those with ACFT experience. The effect of Time was present for ACFT cumulative score, as well as event-level differences in three out of six events. Further research should implement familiarization sessions to minimize a practice effect from influencing results.

KEY WORDS: Military, assessments, practice effect, plyometrics

INTRODUCTION

The new Army Combat Fitness Test (ACFT) is designed to measure a wide range of athletic qualities through six events: 3-Repetition Maximum Deadlift (MDL), Standing Power Throw (SPT), Hand-Release-Pushup (HRP), Sprint-Drag-Carry (SDC), Leg Tuck (LTK), and 2-Mile Run (2MR) (2). The raw performances from each event are converted to arbitrary units (au) on a 0-100 scale, the sum of which determines a soldier's ACFT cumulative score (0-600). Through these events, soldiers are assessed in their muscular strength and power, local muscular endurance, and anaerobic and aerobic capacity. This makes the ACFT more comprehensive than its predecessor, the Army Physical Fitness Test (APFT), which only assessed local muscular endurance and aerobic capacity (2). Despite the differences between the ACFT and the APFT, warm-up protocols remain largely unchanged (2). The current warm-up protocol, known as the Preparation Drill (PD), consists of 10 exercises that are performed prior to the first event of the ACFT. The exercises included in the PD can be found in Appendix A. However, due to several extended idle periods between each event of the ACFT, performing only the PD prior to the start of the test battery may limit the physiological benefits of the warm-up on performance.

Post-activation potentiation (PAP) is a phenomenon that enhances muscle force production at submaximal levels of calcium saturation and is attributed to an increased myosin light chain phosphorylation in type II muscle fibers (8). This has been quantified by measuring muscle twitch force responses to a bout of muscular activity (8). PAP has been largely stated as the mechanism through which voluntary force enhancement in practical outcomes occurs (27). However, the time course for myosin light chain phosphorylation rarely matches that of voluntary force enhancement, inferring that there are other mechanisms contributing to increases in post activation performance (8). A more appropriate term for the performance benefits seen in these protocols is post-activation performance enhancement (PAPE), which describes the voluntary force enhancement following an intervention that is often attributed to PAP but is hypothesized to be driven by other mechanisms such as changes in muscle temperature, muscle/cellular water content, and muscle activation (8). Due to the wide range of physical qualities assessed in the ACFT, PAPE was considered in this study as any improvement in performance following an activation exercise (9).

The most prominent use of PAPE in the literature is in the application of power outcomes (27). There are three broad categories of PAPE protocols used to achieve increased power performance in the literature: eccentric overload, high-intensity load exercises, and plyometric exercises.

Beato et al. demonstrated increased countermovement jump (CMJ) performance following an eccentric overload protocol that consisted of three sets of eccentric-only half squats at maximal power using a flywheel ergometer (3). The application of eccentric overload training presents an accessibility issue due to the need for specialized equipment or spotters. Due to this, the most-common form of PAPE protocols used in the pursuit of increasing power performance are high-intensity exercises (27).

Improvements in outcomes such as the CMJ and sprinting have been shown using the back squat, typically with intensities of 80-90% of 1RM (5, 15, 21, 13, 14). While high-intensity exercises are more accessible when compared to eccentric overload exercises, there is still the requirement for applying external load and the associated equipment necessary to do so. This is particularly challenging when applying PAPE in the context of team sport events where resistance training equipment is rarely available in close proximity to the practice or competition environment.

An understudied area of research includes the examination of plyometric exercises within PAPE protocols. Turner et al. examined 10-m and 20-m sprint performance after three sets of 10 repetitions of alternate-leg bounding using body mass, and body mass plus 10%, compared to a walking control condition. Improvements in sprint performance were observed in the non-weighted plyometric condition after 4 minutes of recovery when compared to control exercise, and in weighted plyometric condition after both 4 and 8 minutes of recovery (25). More recently, Johnson et al. assessed the effects of a warm-up routine that incorporated drop jumps on the force generating capacity of the quadriceps muscles. Force generation was assessed by changes in electrically evoked isometric muscle twitches recorded after both the drop jumps and a low-paced walk control condition. Increased peak twitch torque was observed in the drop jump condition, but the effect dissipated within 6 minutes (17).

Middle-distance (2-10 minutes) and long-distance (>10 minutes) performance are commonly thought to be limited by physiological factors such as VO_{2max}, movement economy, and fractional utilization of VO_{2max} (7). It is well established that neuromuscular factors contribute, giving the rationale for consistent strength and power training throughout the year for athletes of these disciplines (3). Optimizing neuromuscular activation acutely during the warm-up up period immediately prior to performance is also a valuable strategy to implement. Typical activities used to achieve this end include brief periods (~20-30 seconds) of high-intensity running known as “strides”, and other running-specific priming activities (7). These priming activities are often preceded by low-intensity jogging, meant to decrease the initial oxygen deficit, and elevate baseline VO_2 consumption (6). However, it is not clear that a precursor to a neuromuscular activating activity is always necessary. For example, van den Tillaar et al. found that intermediate running performance was unaffected when comparing a warm-up consisting of a 10-minute jog followed by six, 50-m sprints versus a warm-up which only included the six, 50-m sprints (26). In fact, the non-jogging group reported lower levels of perceived exertion during the subsequent maximal 3-minute run (26).

During the ACFT, there are inevitable rest periods both after the initial warm-up with the PD, and between events. This creates a scenario where multiple warm-ups throughout the event may be beneficial. There are several other sporting scenarios where this dilemma has been identified. In 2013, Zois et al. found that repeated sprint ability was increased in a group of soccer players after performing a re-warm-up of 5RM leg press compared with a passive recovery control (29). Yanaoka et al. found that a low intensity re-warm-up period (3 minutes of cycling at 30% VO_{2max}) was as effective as a moderate re-warm-up (3 minutes of cycling at 60% VO_{2max}) at improving subsequent sprint performance (28). Both re-warm-up conditions outperformed the passive rest control. This is noteworthy because the data support that lower effort re-warm-up strategies may be effectively implemented while also limiting fatigue. In 2018, a systematic review of 27 articles focusing on the effects of warm-ups and re-warm-ups of soccer performance found that active re-warm-up protocols including PAP and multi-directional speed drills during half-time attenuated temperature and performance reductions (17). Thus, the study design of this investigation evaluated if additional preparation activities were effective in acutely enhancing ACFT performance.

PAPE protocols show promise and practical application in sport and performance settings. However, due to PAPEs ability to affect a wide range of performance outcomes, there are several factors that must be considered when applying PAPE strategies to a specific type of athlete or performance outcome. These considerations include optimal rest interval duration between the intervention and performance, training status of the individual athlete, and absolute strength or overall fitness of the athlete.

Fatigue from PAPE protocols affect participants differently based on training status, with more-trained participants being more resistant to fatigue (27). Additionally, a 2016 meta-analysis comprised of 47 studies and 135 groups for a total of 1954 participants, found that stronger individuals and individuals with greater resistance training experience, tend to exhibit a greater response from PAPE protocols compared to other peer groups (24). In 2021, Guerra et al. found professional soccer players with higher fitness scores as measured by body composition, agility tests, and aerobic capacity experienced a greater benefit in CMJ performance after sled sprints (16). Dinsdale & Bissas found that participants with higher absolute hang clean 1RM observed a stronger PAPE effect on CMJ performance 5 minutes post, whereas that relationship was inverted with participants that had lower 1RM hang clean values, showing PAPE responses at 1-minute post. This suggests that stronger individuals may have a greater capacity to accumulate fatigue, and therefore need longer rest intervals to take advantage of PAPE effects (10).).

While PAPE protocols have been applied to a wide breadth of physical outcomes in the literature, to our knowledge there is currently no data that demonstrates whether differing PAPE protocols, that include both plyometric and high-intensity resistance training exercises, may be applied to a battery of tests consisting of outcomes across the spectrum of physical qualities like the ACFT. Therefore, the purpose of this study was to implement task specific PAPE protocols prior to each of the ACFT events in an attempt to identify if PAPE protocols acutely improve ACFT performance.

METHODS

Participants

A power analysis conducted with G*POWER 3.1 (Universitat Kiel, Germany) determined that 14 participants were needed in the present study for a power of 0.8, with a Cohen's *d* effect size = 1.5 to correspond with the upper threshold for a moderate effect size in recreationally trained athletes (23), and an $\alpha = 0.05$. Potential participants were recruited from a pool of 124 members of the Reserve Officers' Training Corps (ROTC) program at a local university. Every member of this ROTC program was invited to participate. 19 college-aged males volunteered and were enrolled in the study. Participant demographics are presented in Table 1. Participants had completed the ACFT at least once in the previous two years.

This study was carried out in full accordance with the declaration of Helsinki as well as the ethical standards of the International Journal of Exercise Science (22). All participants provided written informed consent prior to participation and the Institutional Review Board at the United States Sports Academy approved the protocol.

Table 1. Participant demographics.

Age	20 ± 2 y
Height	176.6 ± 8.4 cm
Body Weight	79.7 ± 13.1 kg

Protocol

The study consisted of two groups who performed two testing sessions, separated by 72 hours in a repeated-measures, crossover, counter-balanced design. In session one, the first group (G1) conducted the ACFT after the standard PD with no additional warm-up activities (control = CON). The other group (G2) conducted the standard PD with the added PAPE protocols (intervention). During the second session, G1 and G2 swapped protocols where G1 completed the PAPE intervention and G2 completed the CON. This design allowed for each participant to serve as their own control and minimize the potential learning or training effect due to the repeated exposure of the design. All PAPE protocols were chosen with the goal of minimizing both fatigue and equipment required. As such, one movement for each event was selected with the intent to potentiate the prime movers in similar movement patterns.

Prior to beginning each session, participants completed a subjective survey describing their performance readiness (18). The survey included two questions. Question one included a 0-10 Likert-type scale, where 0 is unable to perform, and 10 is ready for peak performance (PRS). The second question was intended to measure the same construct of readiness on a visual analog scale that was 100-mm in length and anchored with "Unable to Perform" and "Peak Performance" (VPRS). For both questions, the participant used a writing utensil to mark their subjective readiness relative to each scale. Additionally, after each session participants were asked to complete a rating of perceived exertion (RPE) survey, placing their perceived effort of the session from 0-10 and on another visual analog scale anchored by "No Effort" and "Maximal Effort" (VRPE) (18).

At the beginning of each session, a test administrator led the group through the PD. After completion of the PD, participants were given five minutes to complete additional self-selected activities prior to the start of the standardized 10-minute warm-up up period for the MDL. The five-minute self-guided warm-up was not standardized, nor recorded. Participants were asked to do the same self-selected activities for both sessions. When either group performed the CON condition, participants were given the standard 10-minutes to complete a specific warm-up for the MDL as suggested in official U.S. Army documentation (ATP 7-22.01), which includes: 8-10 repetitions at 25% goal weight or with empty bar (rest 2 minutes), 6 repetitions at 40% goal weight (rest 3 minutes), then 4 repetitions at 50% goal weight (rest 4 minutes or until MDL event starts). At the end of the 10-minute warm-up period, participants completed their MDL with the heaviest weight possible, with a maximum of 154.5 kg.

During the PAPE session, participants were instructed to use the 10-minute warm-up period to work up to a single repetition that was 10% greater than their 3RM goal weight for the day. Participants had the freedom to take as little or as much of the 10-minute warm-up period to accomplish this as they deemed necessary.

Once the last participant in each group completed the MDL event, all participants moved as a group to the SPT area during the PAPE treatment, groups were instructed to perform five consecutive countermovement jumps at any time between the completion of the MDL event, and their turn on the SPT event.

Once the last participant in each group completed the SPT event, all participants moved as a group to the HRP area. During the PAPE treatment, groups were instructed to perform five plyometric pushups at any time between the completion of the SPT event and their turn on the HRP event.

Once the last participant in each group completed the HRP event, all participants were moved as a group to the SDC area. During the PAPE treatment, groups were instructed to perform five consecutive broad jumps at any time between the completion of the HRP event and their turn on the SDC event.

Once the last participant in each group completed the SDC event, all were moved as a group to the LTK area. During the PAPE treatment, groups were instructed to perform five 4.54kg medicine ball slams at any time between the completion of the SDC event and their turn on the LTK event. Participants were instructed to raise the ball above their heads, and forcefully throw the ball into the ground in a downward motion.

Once the last participant in each group completed the LTK event, all participants were moved to the 2MR area, and a 10-minute clock was started during the PAPE treatment, groups were instructed to perform four, 20-m sprints within the first 5 minutes of the 10-minute rest period and rested for the remaining 5 minutes. At the end of the 10-minute rest period, groups performed the 2MR event in as little time as possible.

Between each event, the group completing the CON treatment were instructed to perform no additional exercises or warm-ups. Participants completing the CON treatment could either sit or stand while waiting for the next event. The only exception to this was the self-guided warm-up prior to the beginning of testing.

Following the completion of each testing period, raw performance scores from each participant were converted into the 0–100-point (au) scale for each event and summed to obtain their ACFT cumulative scores.

Participants were not made aware of their score in each event for the duration of the study to minimize the desire to beat one's own score from the previous session. The exception was during the MDL, where obscuring the amount of weight being used presented a safety hazard. Except for the 2MR, rest intervals between the PAPE intervention and the tested event were self-selected. Figure 1 demonstrates the order of events and the PAPE exercises performed before each event during the PAPE session and the CON session.

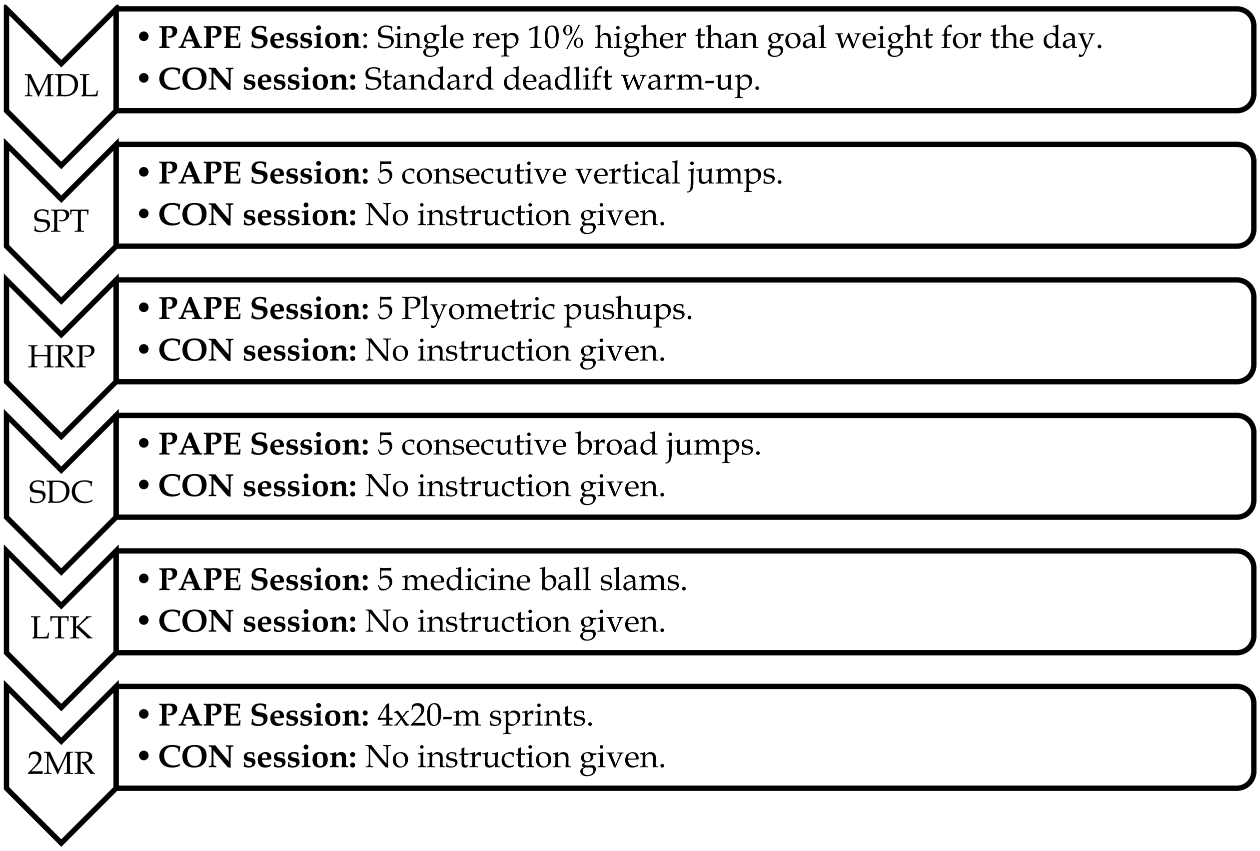

Figure 1. Order of Army Combat Fitness Test (ACFT) events and corresponding post activation performance enhancement (PAPE) exercises.

Statistical Analysis

After completion of both sessions, data were manually entered into Microsoft Excel by the researcher to produce summary statistics and later transferred to SPSS (Version 28) for additional analysis. A two-way ANOVA (Time x Treatment) was used to assess the effect of PAPE treatment on ACFT cumulative scores. Additionally, paired-samples, one-tailed, *t*-tests were used in Excel to evaluate mean differences for subjective measures (PRS, VPRS, RPE, VRPE) and individual event's ACFT and raw scores. Cohen's d effect sizes were calculated to contextualize mean differences.

RESULTS

Summary results are displayed in Table 2 (CON vs PAPE) and Table 3 (Session 1 vs Session 2). The results of a two-way, repeated-measures ANOVA revealed that there was no interaction effect (Time x Treatment) [$F(1,8) = 0.075$, $p = 0.79$] nor main effect of treatment (CON vs PAPE)

[F(1,8) = 0.084, p = 0.78]. However, there was a main effect of Time (Session 1 vs Session 2) [F(1,8) = 58.87, p < 0.001, d = 0.25].

To further investigate event-level differences, a one-tailed, paired-sample t-test was conducted on each event. Event-level ACFT scores (au) differed between Session 1 and Session 2 for MDL (p = 0.02, d = 0.14), 2MR (p < 0.01, d = 0.69), LTK (p = 0.03, d = 0.17), and ACFT cumulative score (p < 0.01, d = 0.25). Event-level raw performance scores differed between Session 1 and Session 2 for MDL (p = 0.02, d = 0.15), and 2MR (p < 0.01, d = 0.69).

To investigate differences in perceived readiness and exertion between treatment (CON vs. PAPE) and time (Session 1 vs. Session 2) a one-tailed, paired-sample t-test was conducted. There was no difference between the PRS (p = 0.21) nor the VPRS (p = 0.43). Additionally, the same can be said for RPE (p = 0.39) and VRPE (p = 0.42). When comparing by time (Session 1 vs. Session 2), there were no differences between either of the categorical scales of readiness or exertion: PRS (p = 0.07) and RPE (p = 0.08). However, there were differences when comparing the analog equivalents by time: VPRS (p = 0.02, d = 0.48) and VRPE (p = 0.04, d = 0.49). Of note, one participant used fractional responses on the categorical scales, those data were removed for the purposes of analysis.

Table 2. Summary statistics for all variables related to the CON vs PAPE. No difference was observed in any of the event-level or cumulative scores, except in the sprint-drag-carry (SDC) event in which a negative performance effect was observed.

Performance Variable	CON		PAPE	
	ACFT Score	Raw Score	ACFT Score	Raw Score
MDL (au/kg)	88 ± 12	130 ± 26 kg	87 ± 13	128 ± 27 kg
SPT (au/m)	82 ± 12	9.8 ± 1.9 m	84 ± 10	10.0 ± 2.0 m
HRP (au/reps)	86 ± 10	46 ± 11 reps	86 ± 10	46 ± 11 reps
SDC (au/min)	97 ± 7	1.6 ± 0.2 min	95 ± 8 *	1.7 ± 0.2 min *
LTK (au/reps)	87 ± 11	13 ± 6 reps	88 ± 11	14 ± 6 reps
2MR (au/min)	92 ± 8	14.5 ± 1.3 min	92 ± 9	14.5 ± 1.4 min
Cumulative (au)	532 ± 42	NA	531 ± 43	NA
Subjective Measures				
	CON		PAPE	
Readiness (PRS/VPRS)	6 ± 1	60 ± 14 mm	7 ± 2	60 ± 17 mm
Exertion (RPE/VRPE)	7 ± 2	72 ± 15 mm	7 ± 2	73 ± 14 mm

* Denotes difference between CON and PAPE (p < 0.05).

Table 3. Summary statistics for all variables related to the Session 1 vs Session 2. Performance improvements were seen in ACFT scores (au) for MDL, LTK, 2MR events and ACFT cumulative score. Performance in raw score was observed in the MDL and 2MR events. Additionally, differences were observed in analog measures of readiness (VPRS) and exertion (VRPE).

Performance Variable	Session 1		Session 2	
	ACFT Score	Raw Score	ACFT Score	Raw Score
MDL (au/kg)	87 ± 13	127 ± 27 kg	89 ± 12 *	131 ± 25 kg *
SPT (au/m)	83 ± 12	10 ± 1.9 m	83 ± 12	9.8 ± 1.9 m
HRP (au/reps)	86 ± 11	46 ± 11 reps	86 ± 10	46 ± 11 reps
SDC (au/min)	95 ± 8	1.7 ± 0.2 min	96 ± 6	1.6 ± 0.2 min

LTK (au/reps)	86 ± 11	14 ± 6 reps	88 ± 12 *	14 ± 6 reps
2MR (au/min)	90 ± 8.6	14.9 ± 1.4 min	95 ± 6.0 *	14 ± 1.1 min *
Cumulative (au)	527 ± 44	NA	537 ± 40 *	NA
Subjective Measures				
	Session 1		Session 2	
Readiness (PRS/VPRS)	7 ± 1	64 ± 11 mm	6 ± 2	56 ± 18 mm *
Exertion (RPE/VRPE)	7 ± 2	69 ± 16 mm	8 ± 2	76 ± 12 mm *

*Denotes difference between Session 1 and Session 2 ($p < 0.05$).

DISCUSSION

The aim of the present study was to examine if event-specific PAPE protocols would have a beneficial effect on subsequent ACFT performance in Army ROTC cadets. The results show that there was no effect of the PAPE protocols on overall ACFT cumulative score. However, at the event-level, there was a trivial (d=0.23) negative performance effect in the sprint-drag-carry event. Interestingly, there was a main effect of time for ACFT cumulative score, and event-level ACFT scores in the MDL, LTK, and 2MR. When comparing raw performance data, this effect was only seen in the MDL and 2MR. These improvements indicate the presence of a practice effect that was potentially strong enough to mask any effects related to an intervention or fatigue.

Additionally, there was no effect of treatment (CON vs. PAPE) on subjective measures of readiness or exertion. However, there was a main effect of time (Session 1 vs. Session 2) on readiness and exertion when measured using the analog 100-mm analog scales. Specifically, VPRS was lower prior to Session 2, and VRPE was higher after Session 2, which was also associated with an improvement in overall ACFT score, as noted above. This provides further evidence that a practice effect was observed between Session 1 and Session 2. Future research investigating an intervention's effect on ACFT protocols should include familiarization sessions (at least two) to minimize or eliminate the practice effect from influencing results.

There are several reasons that could explain the lack of PAPE effect in the majority of ACFT events in this study. In the MDL event, a single repetition at 10% higher than the participant's goal weight was used as the PAPE stimulus prior to the 3-rep max effort of the event. This is a unique scenario that is not found in the PAPE literature. Most of the existing research investigates the effects of a high-intensity load exercise on muscular power outcomes such as sprint performance (13, 20) or CMJ performance (12). Additionally, there is evidence that a high-intensity load exercise may improve muscular endurance outcomes by increasing repetitions to fatigue (8). The MDL event falls between these two applications of PAPE investigated thus far, and further research is required to determine whether a PAPE protocol can be practically implemented to improve acute performance. Another factor that may limit the results of the present study is that there was an artificial upper limit of performance placed on this event. The maximum possible score for the MDL event is 154.5 kg, and therefore participants were not permitted to surpass this weight on the test. Eight of the 19 participants achieved this weight in both CON and PAPE treatments, therefore the results from those participants are difficult to interpret. Future research should either remove this limit for the purposes of the study, or only recruit participants who fall below the maximum strength threshold so that their results have more relevant applications to improving ACFT scores.

The PAPE effect during the SPT event is another that may have been influenced by incorporating the PAPE procedures as part of a realistic ACFT. The SPT event is conducted immediately after the MDL event, allowing the MDL event to serve as a PAPE stimulus to the SPT event. Rest intervals of 3-7 minutes following heavy resistance exercises were found to provide favorable outcomes for vertical jump performance (11). Although the rest-interval between MDL and SPT events vary in the field depending on the number of participants and efficiency of the test facilitators, this effect is still a relevant consideration when investigating PAPE protocols for the SPT. While the interaction between MDL and SPT events limits the ability to interpret the effect of an additional PAPE protocol that targets the SPT in isolation, it provides useful information because any PAPE protocol for the SPT will have to overcome the MDL-SPT interaction to be practically useful in ACFT performance.

During the HRP event, five explosive plyometric pushups were used as PAPE-inducing stimulus. There was no difference found between CON and PAPE treatments for this event. This finding somewhat contradicts the findings by Alves et al. (1) who observed increased repetitions to failure on the bench press with 75% 1RM after one set of three repetitions with 90% 1RM. The disparate findings suggest that the increased external load of the bench press elicited a PAPE response that could not be replicated with the bodyweight pushups, even when performed with maximal contraction speeds. Further research should attempt to use the bench press exercise as the PAPE stimulus for the HRP event. However, the introduction of additional equipment may limit its practical applicability to ACFT performance in the field.

The SDC event is the one event in which a negative performance effect was observed. Although the effect size was trivial for recreationally trained athletes (21), this finding suggests that the PAPE protocol of five consecutive broad jumps may produce too much fatigue to provide a benefit to performance. This contradicts the previous findings which observed improvements in glycolytically demanding cycling performance following one set of drop jumps (8). This difference may be attributed to differences in the performance outcome. Polis et al. measured performance during a cycling time trial that was performed until voluntary exhaustion (8). The present study differs in that the performance outcome is a set distance and involves multiple athletic components (i.e., sled drag, side shuffle, loaded carry, and sprint).

The most noteworthy findings of the study are the improvements in performance seen during the second session of testing. The MDL event and 2MR event saw improvements in both raw scores and ACFT scores. Additionally, during the leg tuck event, an improvement in ACFT score was observed. Lastly a 10-point improvement of ACFT cumulative score was observed. These results suggest that 72 hours is sufficient recovery time for soldiers conducting the ACFT in the same week to return to baseline performance – even if subjective recovery has not yet returned to baseline. Furthermore, our results support the practice of conducting at least one diagnostic or familiarization ACFT 72 hours prior to the official graded ACFT to help with familiarization and potential improve performance via a practice effect in the second session. Additionally, the timing between the PAPE exercise and the target exercise could be optimized (info from intro paragraph)

Of further interest are the results of the readiness and exertion subjective measures when compared against time. Participants reported being less prepared using the analog VPRS and reported higher exertion on the analog VRPE during the second session where performance was objectively better. This data could be interpreted in several ways. First, it could mean that there was a true practice effect and participants had to display greater exertion due to lower physical readiness to perform at or beyond what was achieved in the first session. Secondly, the higher exertion displayed in the second session may somewhat account for the improvement in performance seen, especially since there was such a large improvement in 2MR performance. Lastly, it is possible that participants simply limited their physical effort during the first session due to the knowledge of having to perform the test again in 72 hours.

There were several limitations to the present study. A major limitation is the presence of maximum scores during the ACFT. Participants had little incentive to perform past the established maximum in an event, given the extra fatigue that could accumulate from doing so. This was most evident during the MDL event, where 8 of the 19 participants lifted the maximum weight (154.5kg) during both sessions. The results of the study may have differed if participants were allowed to continue to lift to their true ability. When the data from those 8 participants are removed, the practice effect is intensified (Session 1 = 107.9 ± 18.2 kg; Session 2 = 114.5 ± 18.8 kg; $t(11) = 2.4$, $p = 0.02$, $d = 0.36$). The same limitation is also present in the HRP and LTK events, although only three participants reached the maximum score in the HRP event in both sessions and four participants achieved the maximum score on the LTK event in both sessions. Another limitation of the present study is the proximity of the two testing sessions being separated by only 72 hours. Having the testing sessions further apart could reduce or eliminate the confounding practice effect that was present in this study. Additionally, there were no controls implemented for nutritional considerations or sleep for the duration of the study.

Another possible limitation to the study was the implementation of non-timed self-selected rest intervals between the PAPE exercise and the associated ACFT event. In a study by do Carmo et al. CMJ performance after a PAPE intervention was compared in groups implementing a 4-minute, 8-minute, or self-selected rest interval (11). Participants in the self-selected rest interval group were instructed to rest until they felt fully recovered and able to exercise at maximal intensity, which was an average of 5:57 ± 2:44 minutes. Improvements in CMJ performance were found in the self-selected interval group when compared to both control (8 minutes) and the fixed interval (4 minutes) groups (11). However, since the subjects in the present study did not have their rest intervals timed, it is possible that they implemented improper rest intervals. A 2019 meta-analysis by Dobbs et al. found rest intervals between 3-7 minutes provided favorable outcomes in vertical jump performance, while rest intervals less than 3 minutes were detrimental to performance (12).

There are several recommendations that come because of the current study's findings and limitations. The most impactful recommendation that future research should consider is the presence of a practice effect. 16 of the 19 participants (≈ 84%) had a higher ACFT score on their second attempt. However, two out 19 (≈ 11%) did worse on their second attempt , and one out of 19 (≈ 5%) matched their first score. Second, is the removal of the event-level maximum scores during the ACFT. When investigating potential effects of a post-activation protocol, it is essential that the performance outcome does not have constraints outside of the participant's own performance. Further exploration of PAPE effect on the individual events of the ACFT should be done to identify the events that would benefit the most from an intervention. Lastly, once events that benefit from post-activation protocols have been identified, it is then crucial to investigate whether training status meaningfully affects a participant's response to a post-activation protocol.

The present study does not provide support for the practice of implementing PAPE protocols prior to each event in this population. However, the results do provide support for the practice of conducting a familiarization ACFT in the same week as the graded ACFT to ensure soldier's achieve scores that are reflective of their physical capacity. Additionally, this study provides an ecologically valid effect size related to the short-term training effects (i.e., familiarization or practice) on ACFT performance; from which future studies can utilize.

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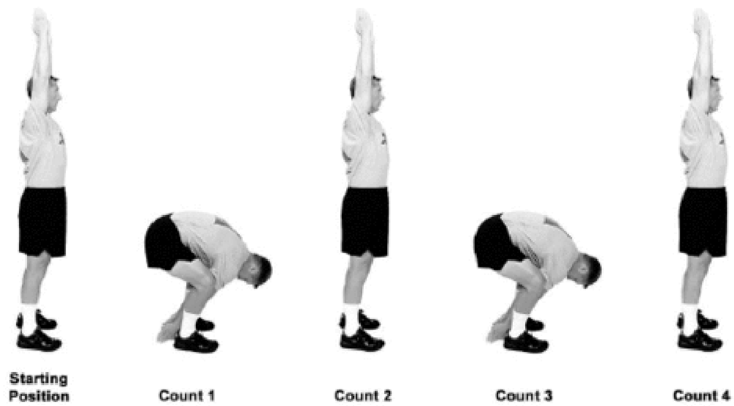
APPENDIX A

Preparation Drill Exercises (FM 7-22)

PD Exercise #1

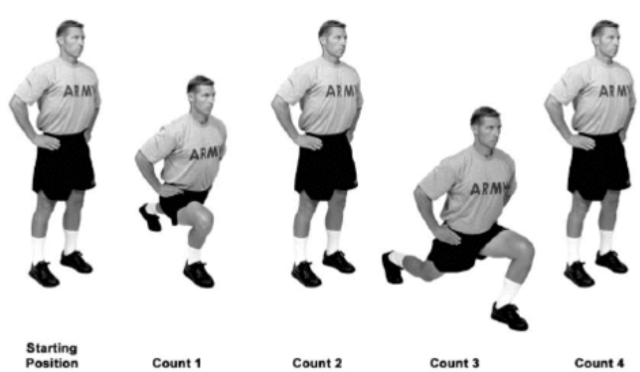
The Bend and Reach



Note: Performed at a slow cadence for 5-10 repetitions

PD Exercise #2

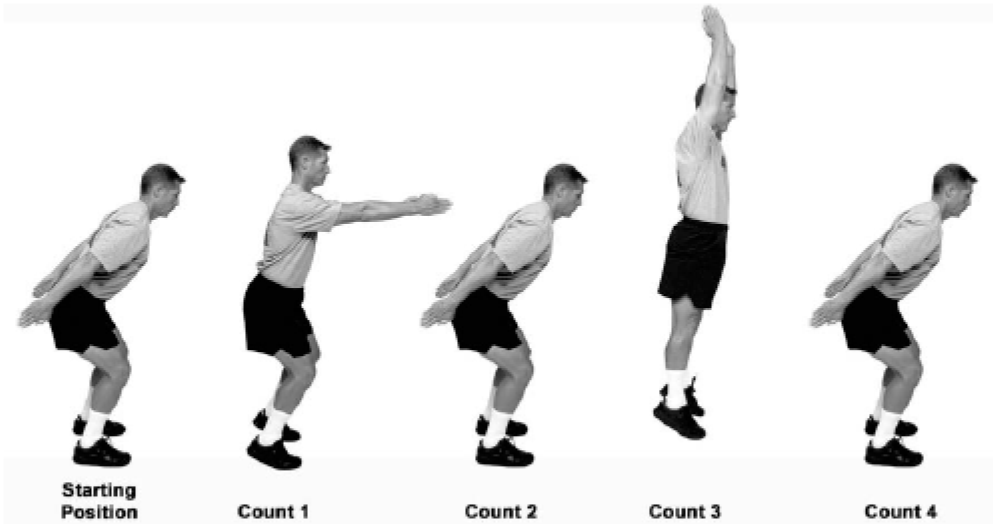
The Rear Lunge



Note: Performed at a slow cadence for 5-10 repetitions

PD Exercise #3

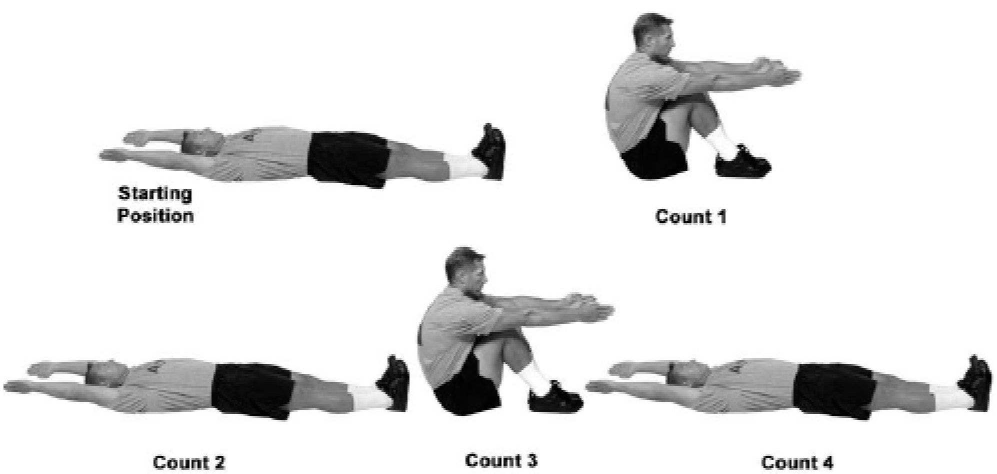
The High Jumper



Note: Performed at a moderate cadence for 5-10 repetitions

PD Exercise #4

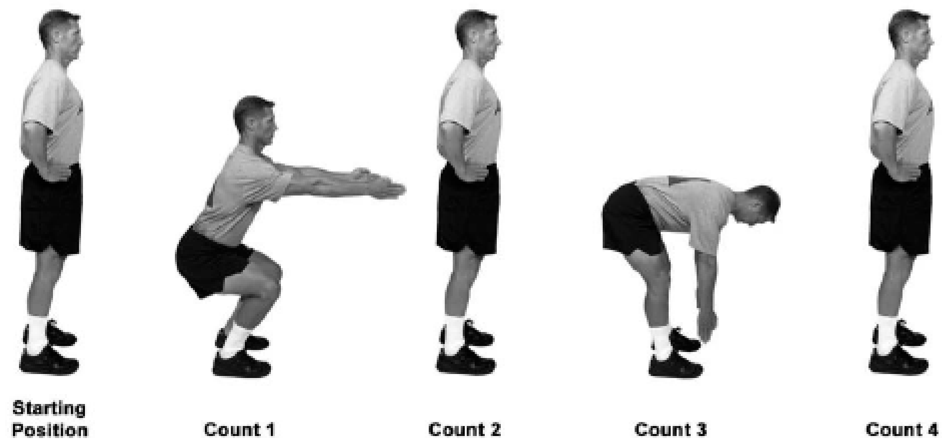
The Rower



Note: Performed at a slow cadence for 5-10 repetitions

PD Exercise #5

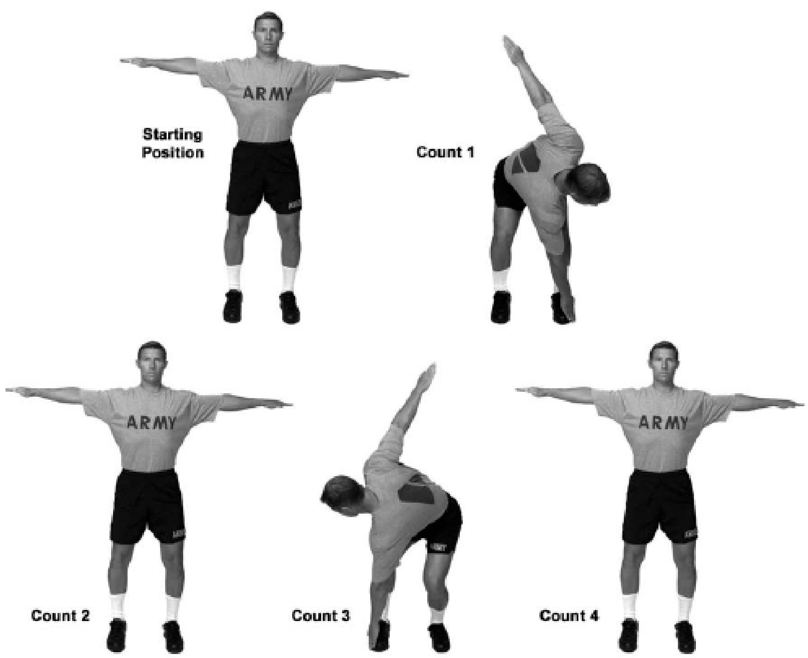
The Squat Bender



Note: Performed at a slow cadence for 5-10 repetitions

PD Exercise #6

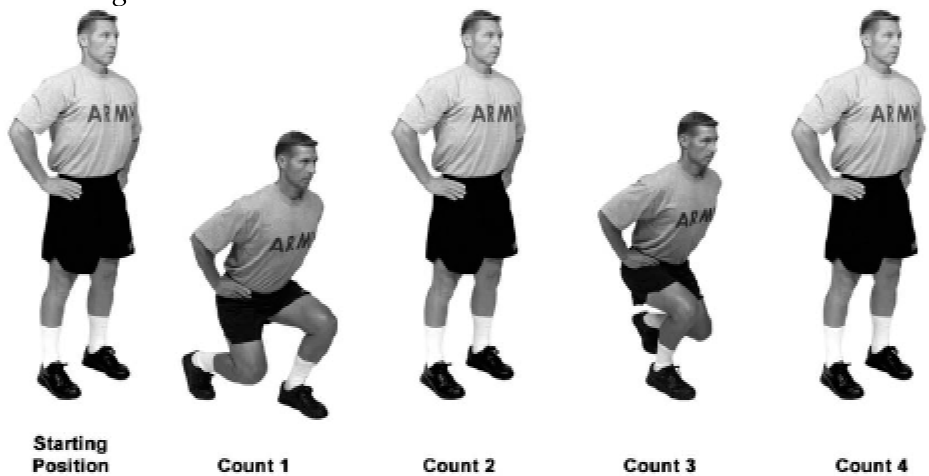
The Windmill



Note: Performed at a slow cadence for 5-10 repetitions

PD Exercise #7

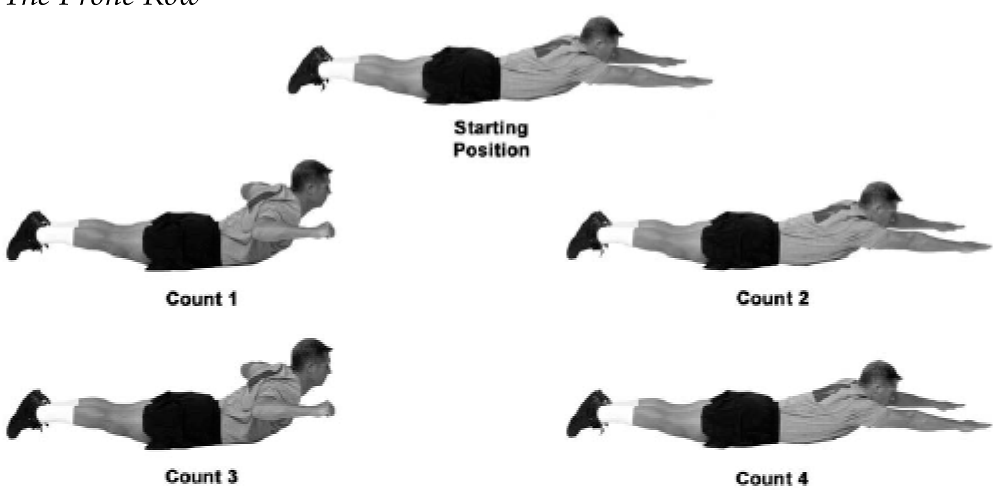
The Forward Lunge



Note: Performed at a slow cadence for 5-10 repetitions

PD Exercise #8

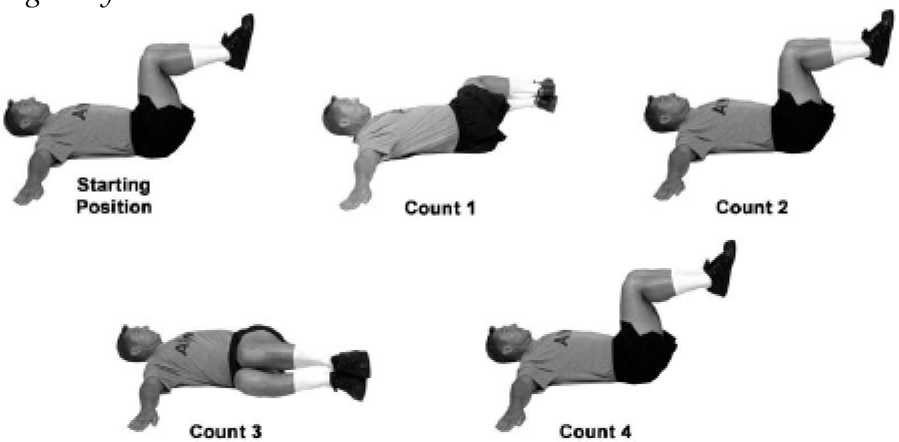
The Prone Row



Note: Performed at a slow cadence for 5-10 repetitions

PD Exercise #9

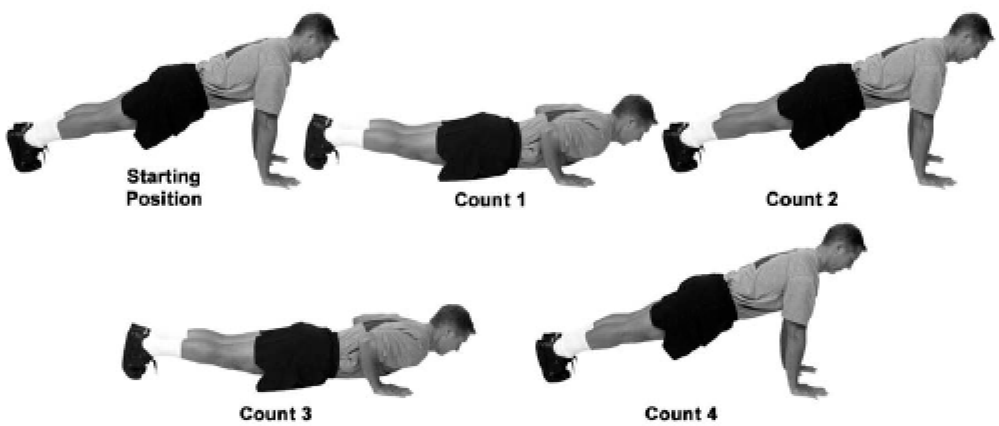
The Bent Leg Body Twist



Note: Performed at a slow cadence for 5-10 repetitions

PD Exercise #10

The Push-up



Note: Performed at a moderate cadence for 5-10 repetitions