Effect of Lumbar Progressive Resistance Exercise on Lumbar Muscular Strength and Core Muscular Endurance in Soldiers

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ABSTRACT Objectives: Low back pain is common, costly, and disabling for active duty military personnel and veterans. The evidence is unclear on which management approaches are most effective. The purpose of this study was to assess the effectiveness of lumbar extensor high-intensity progressive resistance exercise (HIPRE) training versus control on improving lumbar extension muscular strength and core muscular endurance in soldiers. Methods: A randomized controlled trial was conducted with active duty U.S. Army Soldiers ($n = 582$) in combat medic training at Fort Sam Houston, Texas. Soldiers were randomized by platoon to receive the experimental intervention (lumbar extensor HIPRE training, $n = 298$) or control intervention (core stabilization exercise training, $n = 284$) at one set, one time per week, for 11 weeks. Lumbar extension muscular strength and core muscular endurance were assessed before and after the intervention period. Results: At 11-week follow-up, lumbar extension muscular strength was 9.7% greater ($p = 0.001$) for HIPRE compared with control. No improvements in core muscular endurance were observed for HIPRE or control. Conclusions: Lumbar extensor HIPRE training is effective to improve isometric lumbar extension muscular strength in U.S. Army Soldiers. Research is needed to explore the clinical relevance of these gains.

INTRODUCTION

Low back pain (LBP) is very common, costly, and disabling for active duty military personnel and veterans.[1,2] The physically demanding and psychologically stressful environments in combat have been implicated as factors related to the high incidence of LBP in military personnel.[1–3] A key risk factor for LBP is deconditioned back and core muscles that are unable to provide the physical forces needed to perform daily activities and work.[4,5] Individuals with LBP exhibit a loss of trunk muscle strength and endurance,[5,6] lumbar muscle fatty infiltration,[5] abnormal core muscle activation patterns,[7] and spinal instability.[7]

These relationships suggest that programs for prevention and treatment of LBP in the military should emphasize development of the back and core muscles through targeted exercise training to help counteract the physical demands placed on the warfighter. Although core exercises are usually part of the military's physical training, no gold standard approach exists to improve functional capacity of the back and core muscles. George et al[8] demonstrated that 5 minutes of core stabilization or traditional sit-up exercise plus brief psychosocial education resulted in reduced incidence of LBP in U.S. Army Soldiers. However, effect sizes observed were modest, which the authors speculated could be attributable to a suboptimal exercise intensity (i.e., too low).

High-intensity progressive resistance exercise (HIPRE) for the lumbar extensor muscles has been shown to result in large muscular strength gains in healthy, college-age civilians,[9–11] useful for prevention of LBP in coal miners,[12] and effective for the treatment of chronic LBP in the general population.[13,14] However, HIPRE for the lumbar extensor muscles has not been assessed in military populations. Although some aspects of exercise training programs in civilians may be generalizable to military populations, the active duty military setting is unique and, therefore, knowledge gained from other populations may not be translatable. Therefore, assessing efficient and effective strategies specifically in the military to achieve optimal strength and fitness is a priority. The purpose of this study was to assess the effectiveness of HIPRE training for the lumbar extensor muscles versus control on improving lumbar extension muscular strength and core muscular endurance in U.S. Army Soldiers.

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METHODS

Design

This study was a mixed methods, cluster randomized controlled trial with two intervention arms (experimental and control), an 11-week intervention period, and assessments before and after the intervention period. The study was designed as a proof-of-concept and feasibility study assessing the impact of HIPRE training in a complex environment (active duty U.S. Army Soldiers in combat medic training) on improving a desired physiological parameter (lumbar extension strength), which is linked to LBP.[5,15]

Participants

All participants were active duty U.S. Army Soldiers training to become combat medics at Fort Sam Houston, San Antonio, Texas. To be enrolled in the study, prospective participants first underwent screening procedures to evaluate eligibility. Potential candidates were required to be between 18 and 35 years of age and English-speaking/reading. Potential candidates were excluded from participation if they had any conditions that would preclude their ability to safely complete the interventions (e.g., cardiovascular contraindications, inflammatory disease, and spinal surgery), were seeking or receiving treatment for LBP, or were performing progressive resistance exercises for the lumbar extensor muscles other than those included in standard military fitness programs. All participants provided informed consent and the study was approved by the San Antonio Military Medical Center Institutional Review Board.

Sample Size

To estimate sample size, we considered lumbar strength gains observed in four previous studies,[9,11,16,17] normative data (MedX, Ocala, Florida), and the hypothesized fitness level of the target population. We hypothesized that lumbar extensor HIPRE training would result in a 25% improvement (effect size of approximately 0.80) in lumbar extension muscular strength compared with control following the 11-week training period. We estimated that the number of participants per cluster (platoon) would be approximately 35. Since no evidence is available to suggest differences among platoons, we estimated that the intracluster correlation (ICC) would be $\leq$0.20. On the basis of the hypothesized effect size, cluster size, and ICC, 12 clusters with a total of 426 participants with evaluable data at follow-up would be needed to obtain at least 80% power at the 0.05 level of significance with a two-sided test.

Baseline and Follow-up Assessments

Following screening and before randomization, all eligible participants underwent baseline assessments, including self-reported questionnaires; anthropometric measurements; and tests of isometric lumbar extension muscular strength, dynamic lumbar extension muscular endurance, and isometric core muscular endurance. The same assessments were conducted approximately 1 week after the 11-week intervention.

Isometric lumbar extension muscular strength was assessed with a lumbar dynamometer (MedX).[11,18] The lumbar dynamometer assesses isometric lumbar extension muscular strength (torque) and accommodates dynamic resistance exercise in the seated position over a 72° sagittal range of motion.[9,17] Maximum lumbar extension torque assessed as maximum voluntary isometric contraction (MVIC) in lumbar extension muscular strength (Nm) was recorded at seven positions: 72°, 60°, 48°, 36°, 24°, 12°, and 0° of lumbar flexion. At each position, the participant gradually built up force against a back pad and pushed as hard as possible for at least 1 second using a monitor for visual feedback of performance. The examiner verbally encouraged the participant to generate maximum torque. Features of the dynamometer allowing for accurate and reliable assessment of lumbar extension muscular strength are described elsewhere.[9,17]

After the strength test and a 5-minute rest, dynamic lumbar extension muscular endurance was assessed with the lumbar dynamometer.[19] The load for the dynamic muscular endurance test was 50% of peak MVIC determined from the strength test. Each repetition was performed throughout a 72° range of motion in the sagittal plane, taking approximately 7 seconds to complete the repetition. The examiner verbally encouraged the participant to perform as many repetitions as possible to volitional fatigue. The standardized procedures for dynamic muscular endurance testing on the dynamometer was adapted from a previously described protocol that was found to be reliable.[19] The test at the follow-up time point was performed with the same absolute load as the baseline test.

After the lumbar extension muscular endurance test and a 5-minute rest, isometric core muscular endurance was assessed with the prone static plank test.[20] To start, the participant assumed the following position: prone on a floor mat, upper body elevated and supported by elbows; hips and legs elevated from floor to achieve neck, trunk, and lower extremity alignment in the sagittal plane; body supported on forearms and toes; elbows directly under the shoulders; ankles at 90°; scapulae stabilized with elbows at 90°; and spine in a neutral position. The test began (i.e., recording time in seconds) as soon as this position was achieved. The examiner verbally encouraged the participant to hold this position as long as possible. The prone static plank test has been shown to be a reliable measure of isometric core muscular endurance.[21]

Randomization

A cluster randomization strategy was utilized in which participants were randomized by platoon to either an experimental group (lumbar extensor HIPRE training—HIPRE, n = 298) or control group (n = 284). The randomization schedule was prepared by computer and balanced to ensure that an equal number of clusters was allocated to each group. Treatment allocation was performed in a concealed manner at the data coordinating center and was revealed to study staff and participants following baseline assessments.

Interventions

The intervention for both groups was initiated approximately 1 week after completion of baseline assessments and randomization. The intervention for both groups took place outside of (i.e., in addition to) normal U.S. Army physical training. As a result, soldiers electing not to participate in the study were not at risk of being exposed to any of the study interventions. The intervention for both groups was administered under supervision of study personnel and consisted of one set of exercise per session, one session per week, for 11 weeks.

Participants in the experimental group performed lumbar extensor HIPRE training with the lumbar dynamometer (Fig. 1). Details of the lumbar extensor HIPRE training protocol are described elsewhere.[11,17] Each exercise training session consisted of a warm-up set of submaximal exercise followed by one set of dynamic, full range-of-motion HIPRE training on the lumbar dynamometer (MedX). For the HIPRE training set, initial resistance for the first session was at a load equaling 50% of peak MVIC determined from the baseline strength test. For the training set, each repetition was performed throughout a 72° range of motion in the sagittal plane in a smooth, controlled manner, taking approximately 7 seconds to complete the repetition. A monitor and speakers attached to the machine provided additional feedback for the participant to perform repetitions in the prescribed cadence and range of motion. Study personnel verbally encouraged the participant to perform as many repetitions as possible to volitional fatigue. When the participant completed 12 or more repetitions, resistance was increased in 5% increments with a pin-loaded weight stack on the dynamometer at the next training session. An adjustable 364-kg weight stack provided resistance from 9 to 182 kg in 0.5-kg increments.

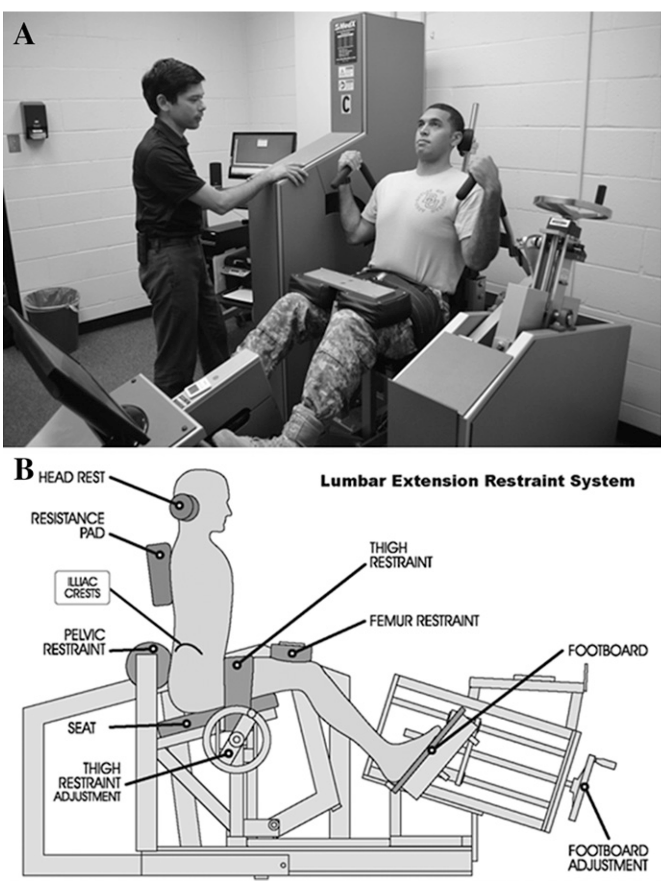

FIGURE 1. Lumbar extensor high intensity progressive resistance exercise (HIPRE) performed by the HIPRE group. (A) Illustration of participant performing HIPRE with the lumbar dynamometer and (B) illustration of the pelvic restraint mechanisms on the lumbar dynamometer.

One set of exercise per session delivered at a frequency of one session per week using this HIPRE training protocol has been shown to be effective to improve lumbar extension strength in healthy civilians.[16,22] In addition, one set per session at one session per week has been shown to be as effective as multiple sets per session and multiple sessions per week to improve lumbar extension strength in healthy civilians.[16,22,23] Given this evidence, along with large operational demands on soldiers, we considered that an exercise dose of one set per session at one session per week would be appropriate to test the study's primary hypothesis.

Participants in the control group performed core stabilization exercise training following a previously established protocol.[24] Each session consisted of five exercises, including the abdominal drawing-in crunch maneuver, horizontal side support, supine shoulder bridge, quadruped alternating arm and leg, and woodchopper.[24] Participants performed one set of six repetitions of each exercise within 1 minute without rest between exercises. Progression was not incorporated for the core stabilization exercises (i.e., participants performed the same 5 exercises at each session).

Although a frequency of one time per week is not the typical dose for delivering core stabilization exercises, we selected core stabilization exercises as the control intervention for the following reasons: (1) to match the attention time provided to the experimental group, (2) to administer a control intervention that was not hypothesized to improve the study's primary outcome of lumbar extension strength, and (3) the core stabilization exercises were successfully implemented in a previous large-scale clinical trial with a similar target population of U.S. Army Soldiers.[24]

Outcome Measures

The primary outcome measure for this study was Nm, defined as the pooled mean value across seven positions of measurement for MVIC: Nm = (MVIC 0° + MVIC 12° + MVIC 24° + MVIC 36° + MVIC 48° + MVIC 60°+ MVIC 72°)/7. Secondary measures included dynamic lumbar extension endurance (number of repetitions) assessed with the lumbar dynamometer and isometric core muscular endurance assessed with the prone static plank test (seconds).

Blinding

Study personnel who assessed outcomes and the statistician were blinded to group assignment. Blinding participants was not possible because they actively participated in the exercise training interventions.

Data Analysis

Means and standard deviations were calculated for baseline demographic variables, and outcome measures at baseline and follow-up. Demographic and baseline variables were compared between the two groups (HIPRE versus control) using independent *t* tests for continuous variables and χ^2 for categorical variables. For the primary hypotheses, differences at follow-up between the two groups on lumbar extension muscular strength (Nm), lumbar extension muscular endurance (repetitions), and core muscular endurance (seconds) were analyzed using linear mixed-effects regression models, accounting for the effects of cluster (platoon) and adjusting for baseline measures. The linear mixed-effects model treats the data as two levels (level 1 for individuals, level 2 for clusters) while also taking into account between-cluster variation. To examine differences between the two groups on repeated measures of lumbar extension strength obtained from the seven angles of measurement (72°, 60°, 48°, 36°, 24°, 12°, and 0° of lumbar flexion), we used a three-level linear mixed-effects model: level 1 for repeated measures of strength (seven angles of measurement), level 2 for individuals, and level 3 for clusters. All linear mixed-effects models were performed using SAS Proc MIXED (SAS Institute, Cary, North Carolina). Individual-specific, within-group changes in lumbar extension muscular strength, lumbar extension muscular endurance, and core muscular endurance from baseline to follow-up were analyzed using paired *t* tests. All analyses were based on the intention-to-treat principle. All tests were two-tailed and considered to be significant at $\alpha = 0.05$, which was set a priori. All analyses were performed using the SAS software, version 9 (SAS Institute).

RESULTS

Disposition of participants throughout various stages of the study is shown in Figure 2. Of the 698 soldiers assessed for eligibility, 645 consented, and 582 were deemed eligible to participate, completed baseline assessments for the primary outcome measure of lumbar extension strength, and were randomized (HIPRE $n = 298$, control $n = 284$). Reasons for ineligibility for randomization were: declined to participate ($n = 43$), did not meet inclusion criteria ($n = 28$), and missed

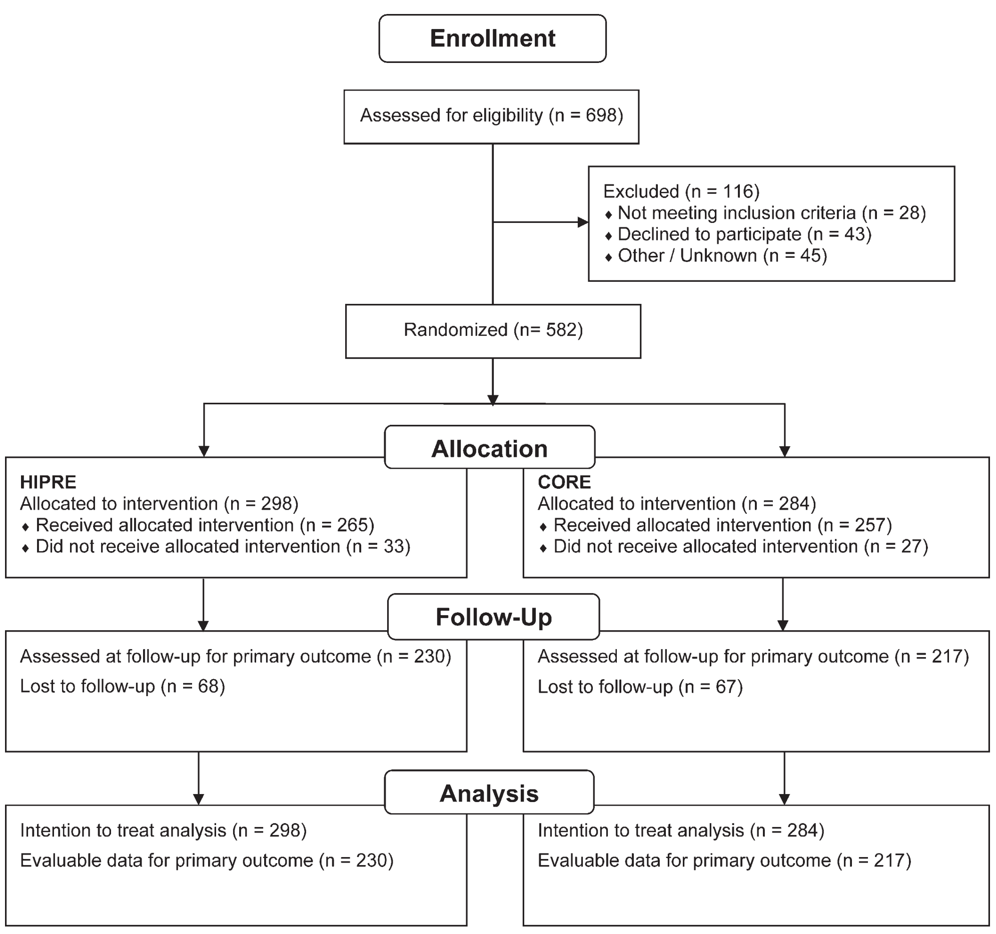

FIGURE 2. Flow diagram of participants through the phases of the study. CORE, core stabilization exercise training; HIPRE, high-intensity progressive resistance exercise.

baseline assessments (e.g., no show) (n = 44), or unknown reason (n = 1). Of the 582 participants who were randomized, 522 started the exercise interventions and 447 completed follow-up assessments for the primary outcome measure. Reasons for missed follow-up assessments were: academic reasons related to U.S. Army (n = 5), changed companies (n = 54), discharged from U.S. Army (n = 7), invalid follow-up strength assessment (n = 5), lost to follow-up during intervention period (n = 15), no-show for follow-up testing (n = 3), pain unrelated to study (n = 7), profile–unable to complete physical training (n = 14), unable to complete follow-up testing, reason unspecified (n = 4), unit time constraints (n = 11), unknown (n = 3), and voluntary withdrawal (n = 7). Dropout rates were similar between the groups.

No significant differences between the HIPRE and control groups were observed in baseline demographics (e.g., age, body height, body weight, and sex) or outcome variables (lumbar strength, lumbar endurance, and core endurance) (Tables I and II). Compared with randomized participants who completed follow-up assessments for the primary outcome (n = 447), randomized participants who did not complete follow-up assessments for the primary outcome (n = 135) had similar characteristics at baseline for most variables assessed, for example, lumbar extension strength (primary outcome measure), health-related quality of life, history of LBP, age, height, weight, and self-reported physical activity. Randomized participants who did not complete follow-up assessments consisted of a higher percentage of females, and had significantly lower baseline lumbar endurance and core endurance scores.

TABLE I. Baseline Characteristics of Participants

	CORE (n = 284)	HIPRE (n = 298)	Total (n = 582)
Continuous Variables			
Age (year)	21.5 ± 3.6	21.8 ± 3.8	21.7 ± 3.7
Body Height (cm)	173.7 ± 8.8	174.6 ± 8.5	174.1 ± 8.6
Body Weight (kg)	75.4 ± 11.3	76 ± 11.5	75.7 ± 11.4
Body Mass Index (kg/m^2)	24.9 ± 2.5	24.9 ± 2.7	24.9 ± 2.6
SF-12 Physical Component Score (0–100)	55.0 ± 4.4	55.1 ± 4.4	55.1 ± 4.4
SF-12 Mental Component Score (0–100)	52.5 ± 7.4	52.7 ± 6.8	52.6 ± 7.1
Categorical Variables			
Sex			
Female	68 (23.9)	67 (22.5)	135 (23.2)
Male	216 (76.1)	231 (77.5)	447 (76.8)
History of Low Back Pain			
No	213 (75.0)	231 (77.5)	444 (76.3)
Yes	69 (24.3)	67 (22.5)	136 (23.4)
Exercised Routinely Before Military			
No	96 (33.8)	108 (36.2)	204 (35.1)
Yes	188 (66.2)	190 (63.8)	378 (65.0)

Continuous variables expressed as mean ± standard deviation. Categorical variables expressed as n (%). CORE, core stabilization exercise training; HIPRE, high-intensity progressive resistance exercise; SF-12, Short Form 12 (health-related quality-of-life questionnaire).[27]

TABLE II. Unadjusted Nm, Dynamic Lumbar Extension Endurance, and Core Muscular Endurance Scores at Baseline and Following the 11-Week Intervention for All Participants

	CORE		HIPRE	
Variable	n	Mean ± Standard Deviation	n	Mean ± Standard Deviation
Nm				
Baseline	284	271.7 ± 92.8	298	275.4 ± 87.0
Follow-Up	217	282.2 ± 93.9	230	309.2 ± 98.0*
Lumbar Extension Endurance (Repetitions)				
Baseline	271	22.0 ± 8.0	285	21.8 ± 7.7
Follow-Up	206	22.2 ± 14.1	212	24.9 ± 8.2*
Core Muscular Endurance (Seconds)				
Baseline	279	172.8 ± 64.1	296	169.0 ± 62.4
Follow-Up	220	165.5 ± 66.5	231	163.8 ± 64.4

*HIPRE > control, $p < 0.05$. CORE, core stabilization exercise training; HIPRE, high-intensity progressive resistance exercise; Nm, isometric lumbar extension muscular strength.

During the 11-week intervention period, no participant in either group reported that they completed or were exposed to exercises assigned to the other group, suggesting that contamination was not an issue. No participant in either group reported that they started any new exercises for the back and core muscles other than those assigned for the study or as part of the U.S. Army's standard physical training program.

For the participants (n = 447) who completed follow-up assessments for the primary outcome measure, the mean ± standard deviation (SD) number of exercise sessions completed was 10.6 ± 1.2 sessions, with no significant difference between the HIPRE and control groups. For the HIPRE group, the mean ± SD dynamic exercise training load at the first and last exercise sessions was 66.5 ± 18.0 kg and 100.4 ± 29.0 kg, indicating a 51% improvement in dynamic exercise load. The mean ± SD number of repetitions completed during each set of dynamic exercise training was 12.8 ± 1.8 repetitions.

No serious adverse events were reported. The observed related or possibly related adverse events were rare and consistent with known side effects of resistance exercise training (e.g., muscle soreness and stiffness). These side effects were generally minor, temporary, self-limiting, and did not impact operations of the soldiers.

Raw isometric lumbar extension muscular strength, dynamic lumbar muscular extension endurance, and isometric core muscular endurance values at baseline and follow-up are found in Table II. A significant improvement in isometric lumbar extension muscular strength was observed within both groups at follow-up compared with baseline (HIPRE: 13.3% improvement, $p < 0.001$; control: 3.3% improvement, $p = 0.004$). On the basis of the linear mixed-effects analyses, adjusted isometric lumbar extension muscular strength (mean ± standard error) at follow-up was 9.7% greater for the HIPRE group compared with the control group (HIPRE: 310.2 ± 6.1 Nm; control: 282.7 ± 6.1 Nm; $p = 0.001$). For the repeated measures of isometric lumbar extension muscular strength across seven angles of measurement, significant effects of group ($p < 0.001$), angle of measurement ($p < 0.001$), and group X angle of measurement interaction ($p = 0.001$) were observed at follow-up. For both groups, isometric lumbar extension muscular strength was linear and descending from 72° (i.e., most flexed position) to 0° (i.e., most extended position). Isometric lumbar extension muscular strength for the HIPRE group was greater than the control group at each angle of measurement, with relatively larger differences between the two groups observed at the more extended angles of measurement.

A significant improvement in dynamic lumbar extension muscular endurance was observed at follow-up compared with baseline for the HIPRE group (11.4% improvement, $p < 0.001$), but not for the control group ($p > 0.05$). Based on the linear mixed-effects analyses, adjusted dynamic lumbar extension muscular endurance (mean ± standard error) at follow-up was 12.3% greater for the HIPRE group compared with the control group (HIPRE: 24.6 ± 1.0 repetitions; control: 21.9 ± 1.0 repetitions; $p = 0.021$).

For isometric core muscular endurance, no significant within group improvements were observed at follow-up ($p > 0.05$). On the basis of the linear mixed-effects analyses, no difference in adjusted isometric core muscular endurance (mean ± standard error) at follow-up was observed between the groups (HIPRE: 161.4 ± 7.2 seconds, control: 160.2 ± 7.2 seconds, $p = 0.871$).

DISCUSSION

The current study found that HIPRE training for the lumbar extensors resulted in significantly greater improvements in lumbar extension isometric muscular strength and dynamic muscular endurance compared with control among U.S. Army Soldiers completing combat medic training. Lumbar extensor HIPRE training was safely and feasibly implemented as part of this study within the usual operations of U.S. Army Soldiers. These findings suggest that lumbar extensor HIPRE training is useful for effectively improving back muscular capacity in soldiers and could be considered for this purpose in similar military settings.

For participants in the HIPRE group of the current study who completed both baseline and follow-up tests, average pre-training and post-training lumbar extension muscular strength values were 273 Nm and 310 Nm, respectively, representing a 13.6% improvement. This improvement was comparable to strength gains observed in a previous study whereby strength testing and exercise training procedures were conducted in the same manner as the current study. In a study with healthy college-age civilians who completed a one session per week, 12-week lumbar extensor HIPRE training program,[11] the average pre-training and post-training strength values were approximately 269 Nm and 307 Nm, respectively, representing a 14.1% improvement. Larger lumbar extension muscular strength gains have been reported in two studies with healthy college-age civilians using a similar exercise training intervention but a different strength testing protocol, whereby a familiarization practice test was performed on a day before the actual baseline strength test.[9,10] The effect of different testing protocols on lumbar extension strength gains in soldiers is unknown and requires further research.

To our knowledge, the effect of interventions on changes in dynamic lumbar endurance (as measured by the test used in the current study) has not been previously assessed. Thus, it is not possible to speculate on clinical meaning of the observed improvements in lumbar extension endurance. These data provide useful information to plan for full-scale prevention trials with clinically meaningful outcomes.

In contrast to our hypothesis, lumbar extensor HIPRE training did not result in significant improvement in core muscular endurance as measured by the prone static plank test. One explanation for this lack of improvement is that a ceiling effect with measurement of core muscular endurance using the prone static plank test in soldiers was likely observed in the current study. The prone static plank test mean score of approximately 170 seconds observed for U.S. Army Soldiers at baseline in the current study was greater than baseline values reported for healthy college-age civilians[21] and firefighters.[25] Furthermore, a potential ceiling effect for this test is consistent with findings of a previous study on floor-based core endurance tests in soldiers.[26] The potential ceiling effect for the plank test requires additional investigation of this test's validity (e.g., sensitivity and responsiveness) in soldiers.

Potential limitations of the current study should be acknowledged when interpreting its findings. Although the observed lumbar extension muscular strength and endurance gains were statistically significant, the clinical impact is unclear. No published data are available to provide guidance on whether the observed effect size for strength gain is meaningful for prevention and treatment of LBP in U.S. Army Soldiers or other at-risk populations. Future research with clinically meaningful outcomes (e.g., incidence of LBP, lost work days related to LBP) is required to test the hypothesis that improving lumbar extension strength can reduce the risk for LBP in soldiers. Another limitation of the current study is that exercise training was conducted on the device used for strength testing for participants in the HIPRE group. Thus, HIPRE group participants may have had advantages in becoming familiarized (learning effect) with the testing device over the intervention period.[11] Furthermore, differences in some baseline characteristics (i.e. sex, lumbar, and core endurance) between participants who completed follow-up and those who did not may indicate that those randomized participants who chose to not complete the exercise intervention may be inherently different regarding their ability to adhere to an exercise training program in the military setting. Factors regarding exercise adherence were not assessed in this study and should be assessed in future implementation research studies. Moreover, this study did not assess implementation or cost effectiveness. Thus, generalizations regarding implementation or large-scale adoption across the military are not possible for HIPRE, which requires specialized equipment that is relatively costly.

The current study was a proof of concept and feasibility study designed to inform future research about lumbar HIPRE training in soldiers. Future research, such as full-scale injury prevention randomized controlled trials with clinically meaningful outcomes (e.g., incidence of LBP, lost work days related to LBP), should be conducted to assess the efficacy of lumbar extension HIPRE training in soldiers. If clinical efficacy of the intervention is established, then additional studies should be conducted to assess implementation (e.g., uptake, adoption, practicality, utility, adherence, and different delivery models for HIPRE training) and cost-effectiveness. Given the relatively high cost and lack of portability of the device used for lumbar extension HIPRE in the current study, the effectiveness of lower tech and lower cost options, such as noncomputerized exercise machines and roman chair benches, to deliver lumbar extension HIPRE training should be assessed. Assuming clinical efficacy and positive outcomes from implementation studies, lower tech and lower cost versions of the exercise devices may be pragmatic appropriate options for large-scale implementation within the military. A commercially available, noncomputerized weight stack device with similar PRE and lumbar isolation mechanisms is relatively inexpensive and mobile. Lower tech and lower cost options could be added to military gyms and potentially added to outdoor physical training areas.

In summary, HIPRE training for the lumbar extensors resulted in significant improvement in isometric lumbar extension muscular strength, but not in core muscular endurance, compared with control in U.S. Army Soldiers. Future research is needed to explore the clinical relevance of lumbar strength gains in the prevention and treatment of LBP in military populations.

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