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Improving Running Performance Using Non-Running Tasks

Darien Lewis
University of Maine - Main

IMPROVING RUNNING PERFORMANCE USING NON-RUNNING TASKS

by

Darien S. Lewis

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Advisory Committee:
Steven J. Elmer, Assistant Professor, Exercise Science, Advisor
Christopher J. Nightingale, Lecturer of Athletic Training, Co-Advisor
Stephen A. Butterfield, Professor, Kinesiology and Physical Education
Gregory A. Zielinski, Former Professor of Climatology and KPE Grad. Student
Sarah Harlan-Haughey, Honors Preceptor of English
Taylor K. Bloedon, RD. Lecturer, Exercise Science

Abstract

For decades researchers and runners have endeavored to improve endurance running performance. Recent evidence suggests that adding resistance training to a running program can improve running performance. Our purpose was to determine if 6wks of **r**esistance **e**xercise via **n**egative **e**ccentrically-induced **w**ork (RENEW), an exercise that increases muscle size, strength, and stiffness, could serve as an effective "non-running" modality for improving running performance. Recreational runners were assigned to a: RENEW (n=7), plyometric (PLYO, n=7), or control (CON, n=7) group. RENEW trained on an eccentric ergometer (3x/wk, 10-30min, 54-66% of peak heart rate) while the PLYO performed a standardized protocol (2-3x/wk, 30min,) for 6wks. Groups continued their normal running. Before and after training, participants performed a 3km running time trial and 5-bound hop test to evaluate running performance and stretch-shortening cycle utilization. During training RENEW increased work rates from 192±44 to 324±89W while exercising at "moderate to somewhat hard" exertion levels (11.9±1.1 to 14.0±0.7 Borg-scale units). Both RENEW and PLYO reported similar levels of muscle soreness (0.68±0.49cm vs. 1.37±1.32cm; group x time interaction, P=0.310). Following training, all groups exhibited similar 3km times and 5-bound hop distances (group x time interactions P=0.232 and P=0.94, respectively). These results demonstrate that RENEW training can be safely tolerated while performing normal running training. RENEW training, however, was not a strong enough stimulus to improve performance *in these recreational runners.* These findings fall squarely in the middle of previous reports indicating 1) improvements, 2) decrements, or 3) no change in running performance when utilizing non-running tasks.

Acknowledgements

This project was supported by the Center for Undergraduate Research at the University of Maine. I would sincerely like to thank all of the committee members of this thesis for all of their support. I would especially like to thank Dr. Elmer, Dr. Nightingale, and Ms. Sarah Lange for all of their input, help, and time. Finally, thank you to all of the participants that took part in the study.

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Introduction

How to improve distance-running performance: A question that athletes, coaches, applied sport-scientists, and researchers have tried to answer for many decades. For as long as people have been running, their performance has been targeted as a changeable factor, essential to competitive success. Whether it is a member of a high school cross-country team, weekend warrior participating in a local 5 km, or elite marathoner, all of these runners share a common goal of racing a given distance as quickly as possible. Because of this, developing methods for improving running performance has implications for a variety of running populations. This thesis aims to explore an alternative non-running based training protocol in terms of its ability to improve running performance.

It is well established that the main determinants of running performance include, maximal oxygen consumption (VO_{2max}), VO_2 at lactate threshold, and running economy (VO_2 required to run a given submaximal velocity). While considerable attention is placed on improving VO_{2max}, it is important to note that running economy can be a better predictor of running performance than VO_{2max} in elite runners (with similar VO_{2max}, Saunders et al., 2004). Similarly, elite runners generally have better running economy than less trained runners (Pollack et al., 1977). Thus, special attention to training protocols that increase running economy to ultimately improve distance-running performance is warranted.

Traditionally, to improve running economy and distance running performance, runners have followed a protocol that included a high volume of low-intensity running (i.e., long slow distance training) (Temple, 1990). More recently, several investigators have demonstrated that "non-running" tasks, such as high-intensity resistance training and explosive plyometric training, can serve as an effective stimulus for improving running economy and distance running performance (for a substantial review see Jung et al. 2003). Indeed, in a groundbreaking study Johnston and colleagues (1997) found that strength training improved running economy in trained female distance runners. Subsequently, Paavolainen and colleagues (1999) demonstrated that explosive strength training (i.e. plyometric training) improved both running economy and 5 km running performance. Further, Spurrs and colleagues (2003) reported that six weeks of aggressive plyometric training improved running economy by ~4%, and that 3 km race time improved by ~3%. Taken together, these findings demonstrate that the use of strength training, a non-running task, can serve as an additional method to improve running economy and race performance.

The improvements in running economy reported by Spurrs and colleagues (2003) were likely due to increased leg spring function as these authors observed a large increase in lower leg muscle-tendon stiffness. In other words, the increased ability to utilize the stretch shortening cycle may have resulted in more powerful strides at the same, original, energy cost (Spurrs et al., 2003). Further, Fletcher and colleagues (2010) reported that running economy and lower leg muscle tendon stiffness are positively correlated: greater running economy meant greater stiffness (Fletcher et al., 2010). These exercises that involve rapid stretching and contracting of the utilized muscles include bounding, jumping, and hopping, and have been shown to improve leg spring stiffness and increase utilization of the stretch shortening cycle (Spurrs et al., 2003; Paavolainen et al., 1999; Ramirez-Campillo et al., 2014).

While these improvements are significant, resistance training and plyometric training can be dangerous and could result in injury. Specifically, these modalities heavily stress eccentric muscle contractions, which can potentially result in significant muscle soreness. Due to the "braking" or "resisting" nature of eccentric contractions, sarcomeres within the muscle are elongated, and may be damaged. Repeated eccentric contractions may then limit force production (Gault, 2013). Delayed onset muscle soreness (DOMS) is a common feature of eccentric exercise, appearing for 24-72 hours post exercise and sometimes lasting even longer. While pain associated with DOMS may be severe, repetition of the same eccentric exercises causes a reduction in post-exercise soreness and quicker recovery time known as the repeated bout effect, which has been accredited to neural, mechanical, and cellular adaptations (Gault et al., 2013; Proske et al., 2005; Penailillo et al., 2013). Because of DOMS and the repeated bout effect, it is crucial to incorporate a progression of exercise intensity, allowing for muscular adaptations to occur while avoiding excess soreness for the participant (Proske, 2005). Thus, it is important to develop alternative resistance training interventions that will elicit changes in running economy and performance without compromising safety.

Resistance Exercise via Negative Eccentrically-induced Work (RENEW) serves as a high-force, low-cost, multi-joint exercise that can be performed safely with both athletic and patient populations. It might also have potential applications for improving running performance. Use of the eccentric ergometer is a highly repetitive task, and targets hip, knee, and ankle joint actions. Briefly, to perform this exercise participants resist the reverse moving pedals of a motor driven ergometer, similar to braking on a fixed-gear bicycle (Figure 1). This, exercise is also similar to the lower phase ("negative phase") of heavy leg press or squat exercises. Interestingly, Elmer and colleagues (2012) reported that 7 weeks of RENEW training improved leg spring stiffness by 10%. Along these lines, Lindstedt and colleagues (2001) authors reported an 11% increase in hopping frequency after 8 weeks of chronic eccentric cycling. In a subsequent study completed with high school basketball players, six weeks of eccentric cycling was found to significantly increase vertical jump height versus a traditional weight program that resulted in no change to jump height (Lindstedt et al., 2002). Collectively, these examples indicate that RENEW training can improve leg-spring stiffness. As suggested by Spurrs and colleagues (2003), improvements in leg spring stiffness likely give rise to improved running economy and running performance. To date, it is unclear if RENEW training will increase running performance and economy.

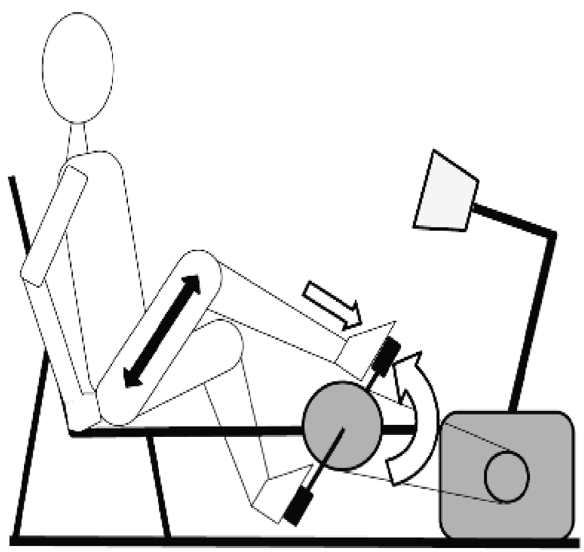

Figure 1: Eccentric cycle ergometer. As pedals move toward the participant (large white arrow), the participant resists by applying force to the pedals (small white arrow). (Figure adapted from Leong et al., 2013)

The purpose of this study was to determine if 6 weeks of RENEW training improved running performance and stretch shortening cycle utilization when added to a regular running routine. RENEW training was compared to a plyometric training group, as well as a control group. Based on evidence from similar studies (Paavolainen et al., 1999; Spurrs et al., 2003, LaStayo et al., 2003; Elmer, 2012), we hypothesized that both the RENEW training group and plyometric training group would improve their 3 km and 5 bound test (5 BT) measures more so than the control group (see Figure 2 for the theoretical framework supporting this hypothesis). We also hypothesized that the RENEW group would improve more so than both the control and plyometric groups. The results of this study could have implications for coaches and athletes, as well as clinicians, who use RENEW for sport training and rehabilitation.

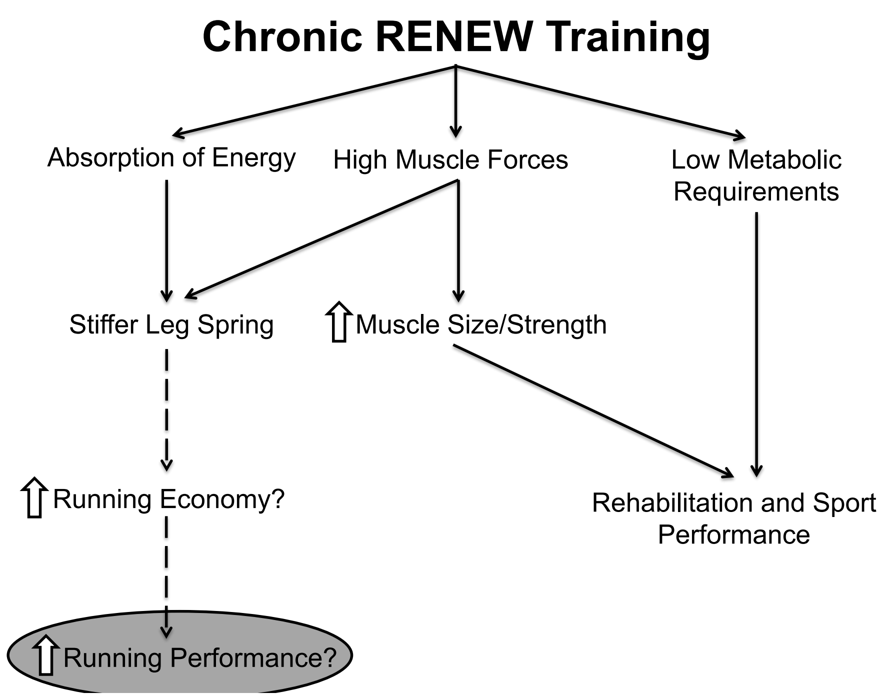

Figure 2: RENEW Theoretical Framework. Repetitive high -force, low-cost eccentric exercise is a potent stimulus for increasing muscle size, strength, and leg spring stiffness (represented by solid arrows). We hypothesize that such changes could also increase running economy and ultimately running performance (represented by dashed arrows).

Literature Review

The following is a review of the primary literature that documents the effects of 1) resistance, 2) plyometric, and 3 eccentric exercise training on running economy and performance and stretch shortening cycle utilization/leg spring stiffness.

Resistance Exercise Training

Traditional resistance training (i.e., “lifting weights”) is often employed to improve muscular strength, muscular endurance, and/or muscular power, (Jung, 2003). Johnston and colleagues (1997) were the first group to determine whether strength training was an effective method to improve running economy in female distance runners. After ten weeks of the training program, the runners improved their running economy by 4%. The authors attributed these improvements to enhanced neural mechanisms, and possible changes in biomechanics from increased leg strength. Results from the study indicated that significant changes in body composition did not occur, an important consideration for distance runners. In a similar study by Storen and colleagues (2008), a 5% increase in running economy occurred after eight weeks of maximal strength training in distance runners. Again, the improved running economy was attributed to the same mechanisms: neural and biomechanical.

Running performance has been attributed to running economy (VO_2 required to run a given submaximal velocity), and was specifically examined by Kelly and colleagues (2008). A ten week strength training program assigned to a group of “recreationally fit” women, in addition to their normal endurance training, resulted in small, non-significant improvements in 3 km performance and running economy (11% and 5%, respectively). In a second study examining both running economy and running performance, Barnes and colleagues (2013) tested heavy resistance training and plyometric training protocols in male and female cross country athletes. Interestingly, results of this study varied substantially between males and females. Both male experimental groups (plyometric and heavy resistance training) experienced increases in 5 km time (i.e., slower running times), indicating that the programs may potentially be detrimental to that particular population. Conversely, both female experimental groups experienced decreases in 5 km time (i.e., faster running times), indicating program success. Despite negative results for male participants, improvements found in the female members of the study have been attributed to increased strength, stiffness, and utilization of stored energy in the legs (Barnes et al., 2013).

Plyometric Training

Paavolainen and colleagues (1999) were the first group to demonstrate positive effects of plyometric training on both 5 km running performance and running economy when added to endurance running training. After nine weeks of plyometric training, male cross-country runners improved 5 km race time (3%) and running economy (8%), both of which were correlated and attributed to neuromuscular adaptations (Paavolainen et al., 1999). In 2003, two studies were published that explored the effects of six weeks of plyometric training. Spurrs and colleagues (2003) found significant increases in 5-bound test (~8%), running economy (~4%), and 3 km time (~3%). The protocol, which controlled for number of ground-contacts during plyometric exercises, supports that this training type increases utilization of stretch shortening cycle utilization, and leg stiffness. Utilizing a low intensity plyometric training program in conjunction with normal running, Turner and colleagues (2003) reported a 2-3% increase in running economy, when evaluated across different treadmill running velocities. Interestingly, this study did not have the same successes with jumping and bounding measures, as established by Spurrs and colleagues (2003).

Emphasizing the importance of small time differences in many running events, and examining plyometric training effects on middle and long distance runners, Ramirez-Campillo and colleagues (2014) demonstrated that their six week training protocol to be highly successful for their participants. In addition, 2.4 km run time decreased by 3.9%, and 20 m sprint time decreased by 2.3%, indicating that positive results may be obtained from the training protocol for both endurance and sprinting events (Ramirez-Campillo et al., 2014).

Eccentric Exercise Training:

It has been well established that eccentric exercises produce high forces at low energy costs, and because of this, several investigators have shifted their attention to the implications that these exercises may hold for a variety of populations. Focusing specifically on RENEW training, LaStayo and colleagues (2000) observed that strength gains and cross sectional area of muscle fibers both increased significantly (36% and 52%, respectively) after training for eight weeks on an eccentric cycle ergometer (similar to the one illustrated in Figure 1). When matching for training intensity on a concentric ergometer (54-66% of age predicted peak heart rate), the authors also reported no changes in fiber size or strength

In a follow-up study, LaStayo and colleagues (2003) examined RENEW's effects on a frail elderly population. Both traditional resistance training and RENEW were tested for 12 weeks in order to determine which was a more effective method of improving muscular function. While each group experienced some leg muscle hypertrophy, it was the eccentric group that significantly improved strength (60%), balance (7%), and stair descent capabilities (21%) (LaStayo et al., 2003). Although this is not directly indicative of running performance or economy improvements, the increase in muscle strength was achieved at a relatively low exertion level, unlike other more traditional training methods.

Elmer and colleagues (2012) completed a seven week RENEW program matched for work against a concentric cycling program, and found improvements in both leg spring stiffness (Elmer et al., 2012). These findings, measured by a series of hopping trials on a force plate and maximal concentric cycling trials, are important indicators of neural adaptations that resulted from the eccentric training. Further, they indicated increased utilization of the stretch shortening cycle, which is an important component of running performance. Also examining maximum power and structural changes to the leg muscles, Leong and colleagues (2013) implemented an eight week eccentric cycling protocol, and found similar results to Elmer and colleagues (2012) and LaStayo and colleagues (2003) studies. In our particular study, RENEW training was performed for shorter and more intense intervals (5-10 minutes; 20-55% of maximum power). Results showed increases in rectus femoris and vastus lateralis muscle thickness (24% and 13%, respectively), and changes in pennation angles. Interestingly, maximum power was found to be 5% higher one week post training, but 9% higher eight weeks post training (Leong et al., 2013). In terms of implications, this finding is extremely important as it points to the need for adequate recovery time when eccentrically-training. Collectively, these results indicate that RENEW can serve as a potent stimulus for improving muscle function (size, strength, stiffness, power) in a broad range of populations. Finally, for a substantial review of eccentric exercise training (including RENEW), I direct the reader to recent work by Isner-Horobeti and colleagues (2013), which covers several of the above studies, as well as many others.

Muscle Soreness with RENEW

While soreness is measured in several of the aforementioned studies (LaStayo et al., 2000, 2003; Elmer et al., 2012; Leong et al., 2013), Penailillo and colleagues (2013) conducted an experiment aiming to determine if the “repeated bout effect” is apparent with eccentric cycling. Having participants complete one concentric cycling session and two eccentric cycling sessions, each separated by two weeks, the researchers found RENEW training to be less metabolically taxing than concentric cycling (Penailillo et al., 2013). Further, they found heart rate and blood lactate to be reduced during the second session of RENEW training when compared to the first. Soreness did not occur after the second RENEW training session. In terms of training, this study establishes that when implemented correctly, RENEW training can be utilized safely at a lower cost and level of discomfort for participants.

Evidence that running economy and performance can be improved by adding resistance training to an existing running program, paired with evidence that neuromuscular and leg spring stiffness changes occur after plyometric and eccentric training are both key components of the current study. Based on the literature described above (see Table 1 for summary), chronic RENEW training will be examined in the current study as a non-running task to improve running performance.

Table 1: Summary of literature reviewed

Study	Participants	Duration	Running Economy	Running Performanc e	Stiffness
Resistance Exercise					
Johnston et al. (1997)	12 runners	3 d/wk for 10 wks	Increased 4%	NR	NR
Kelly et al. (2008)	16 recreationally fit	3 d/wk for 10 wks	No difference	Not significant	NR
Storen et al. (2008)	17 well trained runners	3 d/wk for 8 wks	Increased 5%	NR	NR
Barnes et al. (2013)	50 collegiate XC runners	2 d/wk for ~9 wks	Vary/Uncl ear	Vary (M/F)	NR
Plyometric Exercise					
Paavolainen et al. (1999)	12 elite runners	~2.5 h/wk for 9 wks	Increased 7%	Increased 4%	NR
Spurrs et al. (2003)	8 well trained runners	2-3 d/wk for 6 wks	Increased 5%	Increased 3%	Increase d 13%
Turner et al. (2003)	10 runners	3 d/wk for 6 wks	Increased 3%	NR	NR
Ramirez-Campillo et al. (2014)	18 competitive mid/long distance runners	2 d/wk for 6 wks	NR	Increase: 4%	NR
Eccentric Exercise (RENEW)					
Elmer et al. (2012)	6 active individuals	3 d/wk for 7 wks	NR	NR	Increase d 10%

NR= not reported

Methods

The University of Maine Institutional Review Board approved experimental procedures used in this investigation. The protocol and procedures were explained verbally and all participants provided written informed consent prior to completing any aspect of the study (See Appendix).

Participants: Volunteers for this study were recruited via a flyer, distributed in an email posted to the University of Maine's "Announcements and Alerts" First Class email account, posted in local sports stores, and on Facebook. To be eligible to participate, volunteers were required to be 1) a recreational or competitive runner between 18-44 years of age, 2) currently running at least four hours per week, and 3) have no history of lower-leg injuries. Twenty-one runners participated in this investigation and were placed in three running training groups with similar numbers of males and females:

1) RENEW training group (n=7),
2) Plyometric (PLYO) training group (n=7)
3) Control (CON) group (n = 7).

Participant demographics are reported in Table 2.

Table 2: Participant demographic characteristics

Group (n=7)	**Age** (years)	**Mass** (kg)	**Height** (cm)	**BMI** ($kg.m^2$)	**Running History** (years)
RENEW	22±4	67±6	174±10	22±2	6±4
PLYO	23±5	75±7	175±8	24±3	8±4
CON	24±2	67±11	176±8	22±3	11±5

Experimental Overview: This study took place over the course of eight weeks. During the first week participants performed pre-training exercises which included an individual 3 km time trial run, and a 5 bound hop test (5 BT) to assess running performance and stretch shortening cycle utilization, respectively. Subsequently, participants in the RENEW and plyometric training groups performed six weeks of training, 2-3 times per week (see training protocol below). Seven to ten days after the final training session, participants repeated the 3 km individual time trial and 5 BT. All participants continued their normal running regimes throughout the study, and were required to complete a lab-issued running training log.

Pre- to post-training measures: To determine if running performance and utilization of the stretch-shortening cycle improved in the two experimental groups of this study, an individual 3 km time trial and 5 BT was administered to all participants. Each was asked to schedule a time to go to the New Balance Field House at the University of Maine to fill out a questionnaire, consent forms, and to complete their pre-training measurements. Participants performed a self-selected warm up, and began with the 5 BT. After practicing the 5 BT, the best of three attempts was recorded. This test, as described by Spurrs and colleagues (2003) is a horizontal bounding test that represents the stretch shortening cycle, which may also serve as an indirect marker for leg spring stiffness (Spurrs et al., 2003). Participants were instructed to try and cover the furthest possible distance on each attempt. Following a brief recovery period participants then ran the 3 km time trial on the 191 m indoor track. The individual 3 km run served to represent endurance running. Standardized verbal encouragement and 200 m splits were provided to all runners. These procedures were again performed following the completion of the respective training protocols.

Training:

Eccentric Ergometer Training: Participants performed RENEW training on an isokinetic eccentric cycling ergometer, built by Elmer and colleagues (2012, Figure 1). The ergometer, which drives the pedals in the reverse direction, was set at 60 RPM for each session with seat adjustments made for each individual's height. Participants were instructed to resist this reverse motion, essentially pushing against the pedals as they came toward them. Before training started participants were required to perform three familiarization sessions over a period of seven days (e.g., 5-15 minutes, 30-60 RPM).

The training protocol, adapted from previous studies (Elmer et al., 2012; LaStayo et al., 1999; 2000) required participants to train three times a week for six weeks. Training intensity was based on a percentage of age-predicted peak heart rate and monitored during each training session (Polar, RCX3, USA). Target heart rate for RENEW training sessions started at 54% of peak heart rate during the first week, and increased to 66% of peak heart rate during the final week. The complete 6 week RENEW training protocol is outlined in Table 3. During each training session mean power and total work were quantified using a power meter (Schoberer Rad Messtechnik, Julich, Germany) and mean heart rate was also recorded. In addition, during the final minute of each training session, rating of perceived exertion (RPE) for the "whole body" and "legs only" was obtained using the Borg 6-20 scale (Borg, 1970).

Table 3: RENEW training protocol

Week	Time (min)	HR (% HR_{peak})	Whole Body RPE	Leg RPE
1	10	54	10-11	12
2	15	58	11.5	12.5
3	20	62	12	13-14
4	20	63	11-12	13
5	25	64	12-13	13-14
6	30	66	13	13-14

To ensure that the RENEW protocol was being administered safely, participants were asked to indicate leg muscle soreness during a standardized wall squat movement. Soreness was marked on a 10 cm analog scale (0 cm = no pain, 10 cm = worst pain imaginable). If soreness was greater than 5 cm then training was postponed until soreness values were reduced. This procedure was been adapted from previous studies in Dr. Elmer's laboratory (Elmer et al., 2012; Leong et al., 2013).

Plyometric Training: The plyometric training protocol was implemented based on the procedure described by Spurrs and colleague (2003). Each session began with a standardized warm up, including 20: leg swings, walking lunges, butt kicks, calf raises, body weight squats, and jumping jacks. This warm up progression focused on the muscles that were most heavily incorporated during the training session, and served to help prevent unnecessary strains during the explosive movements. During the first and second weeks, two sessions occurred, followed by three sessions per week for the final four weeks. The complete plyometric training protocol is outlined in Table 4. Exercises occurred in vertical and horizontal planes, as participants were asked to bound, hop, and jump as far, fast, and high as possible. Demonstrations of exercises were provided to participants at the introduction to novel movements. As described above, to ensure that the plyometric protocol was being administered safely, participants were asked to indicate leg muscle soreness during a standardized wall squat movement.

Table 4: Plyometric training protocol

Week	Workout
1	2x10 Squat Jump 2x10 Split Scissor Jump 2x10 Double Leg Bound
2	2x10 Squat Jump 2x10 Split Scissor Jump 2x10 Double Leg Bound 2x10 Alternate Leg Bound
3	2x12 Split Scissor Jump 2x12 Double Leg Bound 2x12 Alternate Leg Bound 2x10 Single Leg Forward Hop
4	3x10 Double Leg Bound 3x10 Alternate Leg Bound (2 days) 2x15 (1 day) 2x12 Single Leg Forward Hop (2 days) 3x10 (1 day) 2x6 Depth Jump (2 days) 2x8 (1 day)
5	2x15 Alternate Leg Bound (1 day) 3x15 (2 days) 2x8 Depth Jumps (1 day) 2x10 (2 days) 2x10 Double Leg Hurdle Jump 2x10 Single Leg Hurdle Hop
6	3x10 Single Leg Forward Hop (1 day) 2x15 (2 days) 3x10 Depth Jump 3x10 Double Leg Hurdle Jump 3x10 Single Leg Hurdle Hop

Statistical Analysis: To describe the progression of the RENEW training, mean power, total work, mean heart rate, RPE body, and RPE legs are reported for descriptive purposes. To compare pre- to post-training changes, separate 3 (group) x 2 (pre-training vs. post-training) mixed repeated measures analysis of variance (ANOVA) procedures were performed on 3 km race time and 5 BT distance values. If the ANOVA was significant then follow up *post hoc t*-tests were performed to identify which groups differed. In addition, muscle soreness values between RENEW and plyometric groups were compared. All data are presented as mean ± standard deviation and alpha was set to 0.05.

Results

General Training Response

All 21 participants completed the six week study. Analysis of running training logs indicated considerable variation in the volume of weekly running training (range: 1-7 h/wk). Both the RENEW and plyometric training groups reported low muscle soreness prior to each training session, (0.68±0.49 cm, 1.37±1.32 cm, respectively, Figure 3) and results from the repeated measures ANOVA procedures revealed that there was no group x time interaction (P= 0.310). Thus, all participants tolerated the protocol's safely.

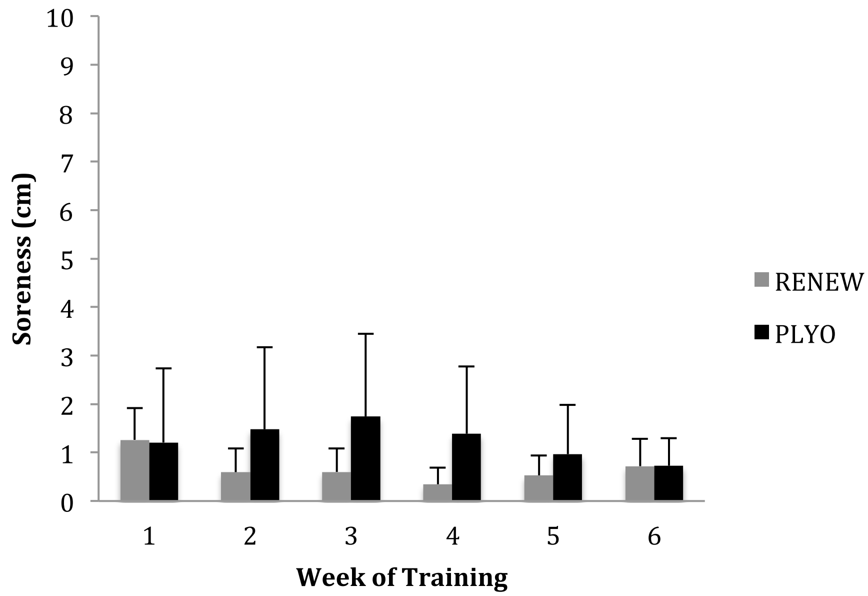

Figure 3: Muscle soreness for RENEW and PLYO training groups (mean± SD).

RENEW Training

Mean heart rate increased from 112±9.5 b·min^{-1} to 127±12.3 b·min^{-1} over the course of the training period, which corresponded to 57 and 64% of HR_{peak}. Thus, participants followed the prescribed training quite well. Similarly, mean power, increased from 192±44 W to 324±89 W representing an increase of 69%. With the progressive increase in training duration and intensity (i.e., power), total work increased, starting at 117±24 kJ during week one, and ending at 577±163 kJ during week six (Figure 4). Finally, RENEW participants rated their training as "moderate to somewhat hard", as indicated by whole body and leg specific RPE values (11.9±1.1 to 14.0±0.7 Borg scale units, Figure 5).

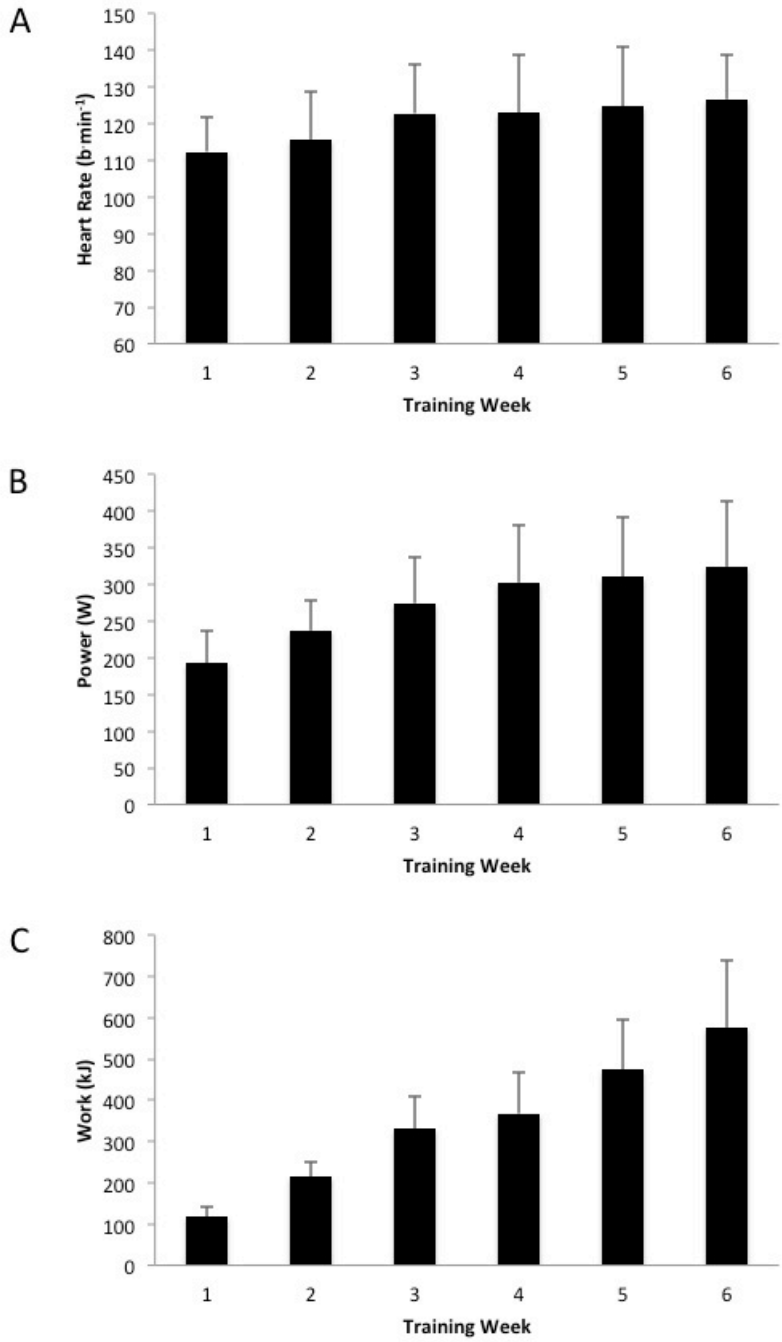

Figure 4: Cardiorespiratory and mechanical responses recorded during RENEW training (mean± SD). (A: average heart rate; B: average power; C: total work)

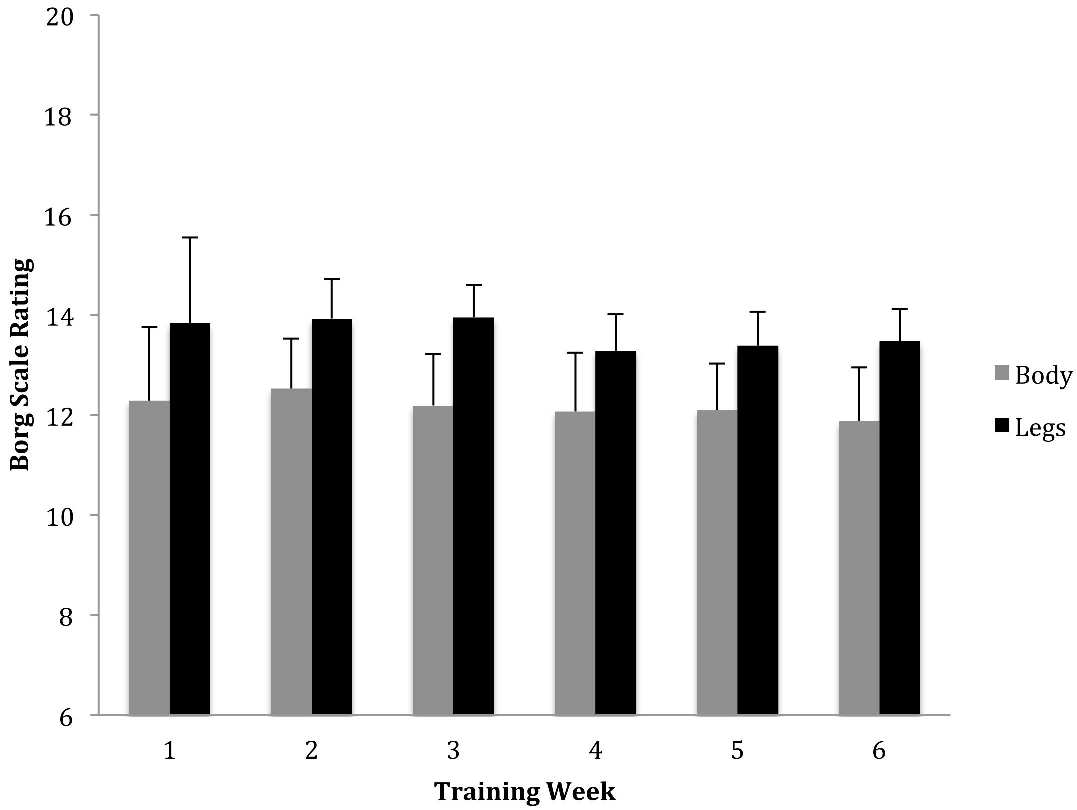

Figure 5: Rating of perceived exertion during RENEW training for whole body and legs only (mean± SD).

Pre-to-Post 3 km and 5 BT Comparisons

Results from the repeated measures ANOVA procedures indicated that there was no group x time interaction for the 3 km run time values (P=0.232, Figure 5). Thus, all groups responded similarly to the running training. Results from the repeated measures ANOVA procedures also revealed that there was no group x time interaction for 5 BT values (P=0.94, Figure 6). There was, however, a significant main effect of time on 5 BT values (P=0.031). This overall improvement in 5 BT could be attributed to motor learning.

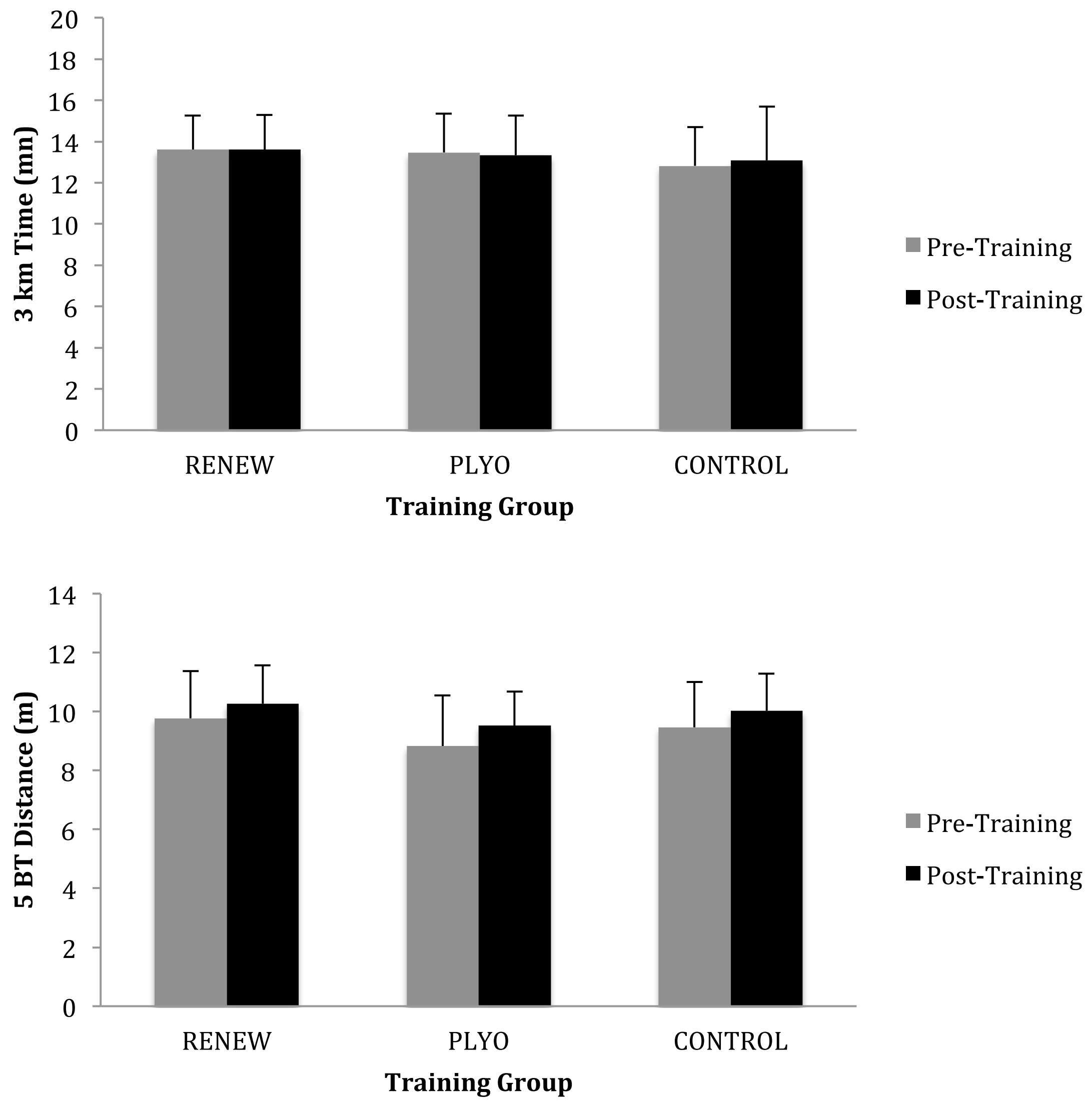

Figure 6: Pre-to-post training changes in 3 km time (top) and 5 BT distance (bottom)(mean± SD).

Discussion

Main Findings

In this investigation, we tested the hypothesis that training with non-running tasks could improve running performance. Specifically, we evaluated pre- to post-training changes in 3 km time and 5 BT distance following 6 weeks of high-force eccentric exercise (RENEW). Results of the study indicated that at the end of the 6-week training period, participants in the RENEW group had similar 3 km times and 5 BT distances, to those in the plyometric and control groups. This suggests that chronic RENEW training was not a strong enough stimulus to improve performance in this group of recreational runners.

RENEW Training

This investigation was the first to utilize RENEW training with runners, and was well tolerated for 6-weeks in conjunction with each participants normal running training. Participants reported low levels of both soreness and exertion, which is consistent with several previous reports using RENEW (Elmer et al., 2012; Leong et al., 2013; LaStayo et al., 2000). Further, RENEW training provided a very controlled modality that was easily modifiable, especially when compared to plyometric training. Interestingly, while strength improvements were not evaluated as a part of this investigation, many participants commented on feeling stronger as the study progressed. Many previous authors have reported that RENEW is an effective method for stimulating improvements in neuromuscular function (e.g., size, strength, power, mobility) (Elmer et al. 2012;

LaStayo et al., 2000; 2003; Leong et al., 2012). With this in mind, additional benefits not measured in this study may have also occurred.

Running Performance

We expected running performance to improve (i.e., faster 3 km time) after six weeks of training, likely due to concomitant improvements in leg spring stiffness and running economy. Specifically, this prediction was based on RENEW-induced increases in leg spring stiffness found by Elmer and colleagues (2012), along with leg spring stiffness-attributed improvements in running economy/performance from plyometric training, (Spurrs et al., 2003). Several previous authors have reported small but significant improvements in running performance (3-4% for 2-5 km) following aggressive plyometric training (Paavolainen et al., 1999; Spurrs et al., 2003; Ramirez-Campillo et al., 2014). In contrast, some investigators (Kelly et al., 2008) have observed no improvements in running performance while others (Barnes et al., 2013) noted impairments to running performance following resistance and plyometric training. Thus, previous reports are varied. The results of this current study, indicating no changes in running performance, fall squarely in the middle of these varied reports. Taken together, these findings indicated that to date there is no solid consensus on the effectiveness of using non-running tasks to improve distance running performance.

There are several factors that could explain these mixed reports. First, the specific running population varied considerably across these investigations. That is, Spurrs and colleagues (2003) and Paavolainen and colleagues (1999), utilized trained endurance runners and elite cross-country runners, respectively, whereas others (including this study) used less trained runners. Second, detecting improvements in running performance (i.e., seconds) can be difficult as participant pacing and/or motivation may overshadowed small improvements that occur with training, especially in less trained runners. Indeed, it was observed that some of the participants in this investigation seemed to be less enthusiastic during post-testing than during their initial pre-testing evaluations. Alternatively, measuring pre- to post-training changes in running economy might offer a more controlled method for detecting adaptations with RENEW as well as other non-running training modalities. Finally, this study required participants to complete 6 weeks of training, similar to Spurrs and colleagues (2003) and Turner and colleagues (2003). Various other reports, however, entailed longer training periods, such as Paavolainen and colleagues (1999), who mandated 9 weeks of plyometric training. Variation in protocol length may have contributed to the different outcomes between these studies.

We also expected that 5 BT distance would increase after the 6 week training period. This anticipated result was based on Elmer and colleagues (2012) finding that RENEW training elicited a 10% increase in leg spring stiffness, which was measured directly with the use of a force plate. The 5 BT was chosen for this study as an indirect measure of leg spring stiffness, as utilized by Spurrs and colleagues (2003) who also reported an ~13% increase in leg spring stiffness following plyometric training. In contrast, results from the current study only indicated that in general 5 BT values improved across all groups (main effect of time) while the group x time interaction was not significant. Data was interpreted these data to represent a learning effect that occurred in participants. Because it is unknown if the 5 BT is directly related to leg spring stiffness, future work evaluating both factors within the same participant group would be highly beneficial.

Limitations and Future Recommendations

Because data was collected from a small group of participants who had a variety of running backgrounds, these individuals may have had different metabolic and/or muscular capacities, which influenced their responses to the training and ultimately running performance. Thus, future work that includes evaluation of a larger number of participants would be beneficial. Further, a suite of measures that includes pre- to post-training changes in strength, a direct measure of leg spring stiffness, and running economy, in conjunction with a 3 km running time trial would expand nicely upon this study, and possibly highlight additional functional benefits associated with chronic RENEW training. Indeed, with these preliminary data from the current study in mind, plans are already in place to perform a larger RENEW training study in a group of well trained runners.

Conclusion

Our findings indicate that recreational runners are able to tolerate 6-weeks of aggressive eccentric exercise training, though no improvements to running performance were elicited. This study was the first to examine RENEW training with a running population, and offers additional insight into the notion of using non-running tasks to improve running performance.

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Appendix

Office of the Vice President for Research
Protection of Human Subjects Review Board

THE UNIVERSITY OF MAINE

5703 Alumni Hall, Room 114
Orono, Maine 04469-5703
Tel: 207-581-1498
Fax: 207-581-1300
www.umaine.edu

MEMORANDUM

TO: Steve Elmer
Lengyel Hall

FROM: Gayle Jones
Assistant to the Institutional Review Board for the Protection of Human Subjects (IRB)

SUBJECT: "Effects of RENEW Training on Neuromuscular Function and Running Performance," #2013-11-12

DATE: February 13, 2014

The above referenced project was approved by the University of Maine's Institutional Review Board for the Protection of Human Subjects (IRB) in an expedited/full Board review. The approval period is 11/20/2013 through 11/19/2014. A continuing review of this project must be conducted by the IRB before the end of the approval period. Although you will receive a request for this information approximately 6-8 weeks before that date, it is your responsibility to submit the information in sufficient time to allow for review before the approval period expires.

Enclosed are approved, stamped copies of the consent documents for this project. The approval for these consents expires on 11/19/2014. **These approved, stamped copies must be duplicated and used when enrolling subjects during the approval period.**

Please remember that each subject must be given a copy of the consent document. Any unanticipated problems or harm to the subject must be reported to the IRB immediately. Any proposed changes to the research must be approved by the IRB **prior** to implementation. Any significant new findings must be reported to the subject.

If you have questions, please contact me at 1-1498. Thank you.

MAINE'S LAND GRANT AND SEA GRANT UNIVERSITY
A Member of the University of Maine System

Author's Biography

Darien S. Lewis was born in Machias, Maine on September 6, 1992. She was raised in Ellsworth, Maine and graduated from Ellsworth High School in 2010. Darien majored in kinesiology and physical education with a concentration in exercise science, and is a member of the women's varsity cross country and track and field teams. She has received a grant from the University of Maine's Center for Undergraduate Research, and was named to Team Maine for having the highest individual GPA on the women's cross country and track and field teams.

Upon graduation, Darien will attend the University of New England as a member of their Doctor of Physical Therapy program.