RECOVERY FOLLOWING AEROBIC EXERCISE:
MODALITIES AND MASTERS RUNNERS

by

KIMBERLY RENEE SHAW

PHILIP A. BISHOP, COMMITTEE CHAIR
MARK RICHARDSON
JONATHAN WINGO
MATTHEW CURTNER-SMITH
RANDALL SCHUMACKER

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ABSTRACT

Running performance can be improved by either increasing training workload or improving recovery quality. Improved recovery rate would allow greater training volumes without the negative effects of overtraining. Masters Runners are middle-aged and older subjects whose recovery may be different from younger runners. The first study reviewed the practicality and effectiveness of modalities thought to decrease time to recovery and increase performance following recovery, specifically in aerobic athletes. The bulk of the recovery modality research has been the investigation of the effect of decreasing muscle temperatures to avoid further damage by the inflammatory response, and the application of heat in an attempt to enhance blood flow in hopes of more rapidly moving harmful by-products out of damaged areas. The second and third studies examined the time necessary for 10 Masters runners (5m, 5f) to fully recover from an all-out 5K run. Participants completed four 5km time trials (TT), counterbalanced and separated by 48, 72, and 96 hours of passive recovery. A significantly faster mean run time (p=0.012) was observed for TT96. Some Masters runners (30% in our study) may be able to fully recover after 96 hours of passive rest, while only 10% of our runners recovered after only 48 hours. The rest needed by Masters runners to fully recover from an all-out 5 km appears individualistic. The third study examined recovery achieved after a maximal-effort 5K run after 24 hours of passive recovery with vitamins C and E, protein, and icing therapeutic recovery techniques (TT24Recov). No significant difference was found between BL and TT24Recov (p = 0.45), while TT96 was significantly faster than BL (1451.28 ± 196.6 s, p = 0.049). Ninety
percent of our Masters runners were fully recovered with 24 hours of passive rest with recovery modalities, or 96 hours of passive rest, only.
DEDICATION

This manuscript is dedicated to James C. Shaw, Jr., Gwendolyn Mock Shaw, David Brian Shaw and Gwendolyn Anderson Mock and in loving memory of James Claude Shaw, Sr., Sallie Burns Shaw, and Peter Robert Mock, Sr.
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<table>
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<tr>
<td>BL</td>
<td>Baseline time trial</td>
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<td>TT</td>
<td>Time trial</td>
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<td>TT24Recov</td>
<td>Time trial following 24 hours of passive recovery and a combination of therapeutic modalities</td>
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<td>TT48, 72, 96</td>
<td>Time trial following 48, 72, or 96 hours of passive recovery</td>
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INTRODUCTION

Little emphasis has been put on recovery from exercise as a means for increasing performance. Recovery from exercise, the time required for trained athletes to fully recover from an exhaustive bout of activity (4); has not been widely studied. While there is a plethora of types of recovery associated with exercise, for this study, we are most interested in training recovery. Coined by Bishop et al. (4) the term training recovery refers to recovery between workouts, and defines training recovery to mean the ability to meet or exceed prior recent performance in a specific activity.

Overtraining is usually thought of strictly in terms of training, yet overtraining might also be expressed as under-recovering. Improved recovery may result in establishment of a higher performance plateau (4, 2). Overtraining is the simultaneous product of both the recovery and the work-out. The answer to overtraining rests in either reducing the workload during training, or perhaps, in improving the quality of recovery (4).

As the US population ages, there is an ever increasing number of “Masters” runners. While there are a variety of studies regarding recovery in young adults (2, 3, 6, 7, 8); surprisingly, there is little research available regarding Masters athletes.
While training protocols remain ever changing, so do the methods thought to aid recovery. Many modalities, once used specifically for treating acute and chronic athletic injuries, have been adapted for use as recovery aids. However, there is little research regarding this use. Therefore, the purpose of this research is three-fold: 1) to review the practicality and effectiveness of modalities thought to decrease time to recovery and increase performance following recovery, specifically in aerobic athletes 2) to determine the amount of time necessary for 10 Masters Runners (5 male, 5 female) fully recover from an all-out 5K run and 3) to determine the difference in the extent of recovery achieved after a maximal-effort 5K run by 10 Masters Runners (5 male, 5 female) after 24 hours of passive recovery with vitamins C and E, protein, and icing therapeutic recovery techniques.
CHAPTER 1

RECOVERY MODALITIES AND AEROBIC PERFORMANCE: A REVIEW OF EFFECTIVENESS AND PRACTICALITY

ABSTRACT

The purpose of this article is to review the practicality and effectiveness of the modalities thought to decrease time to recovery and increase performance after recovery, specifically in aerobic athletes. While training protocols remain ever changing, so do the methods thought to aid recovery. A multitude of modalities exist and are routinely used for the treatment of both acute and chronic athletic injuries, many of which have been adapted for use as recovery aids immediately post performance or at other times between training sessions and or performance bouts. These modalities include: water immersion, cryotherapy, thermotherapy, contrast therapy, massage, ultrasound, compression garments, active recovery, stretching, and electrical muscle stimulation (EMS). Whereas there are many modalities used in sports medicine for treatment of acute and chronic injuries, there is only scant evidence that a few of these may be beneficial to uninjured athletes hoping to reduce recovery time and enhance performance post-recovery. The bulk of the recovery modality research has been the investigation of the effect of decreasing muscle temperatures in order to avoid further damage by the inflammatory response, as well as
the application of heat in an attempt to enhance blood flow in the hope of more rapidly moving harmful by-products out of the damaged areas.

Key words: endurance training, training aids, run training.
INTRODUCTION

For as long as sport has existed, it has been the goal of athletes and their coaches to jump higher, run faster, and be stronger than their opponent. While these goals are understandable, little emphasis has been put on recovery from exercise as a means for increasing performance. Recovery from exercise training, the time required for trained athletes to fully recover from an exhaustive bout of activity; has not been widely studied.

The definition of recovery from training as well as the procedure used to facilitate recovery is dependent on the intensity, mode, duration and frequency of the training. For example, McArdle et al. (24) differentiates the type of recovery procedure as it relates to the intensity of exercise, classifying it as two types: active and passive. They explain that most people generally perform exercise at a steady rate with little lactate accumulation at oxygen consumptions below 55 to 60% of VO$_{2\text{max}}$. In this situation, recovery entails re-synthesis of high-energy phosphates; and replenishment of oxygen to the blood, bodily fluids, and muscle myoglobin. Under these circumstances, passivity facilitates recovery because any additional exercise only serves to elevate total metabolism and delay recovery.

However, when a workout exceeds the maximum steady-rate metabolic level, lactate formation in muscle exceeds its removal rate, and blood lactate accumulates. Because the lactate anion can produce a fatiguing effect on skeletal muscle, independent of associated reductions in pH, any procedure that accelerates lactate removal probably augments subsequent exercise performance, thereby speeding recovery (24). Thus, performing light aerobic exercise in recovery (i.e. active recovery) accelerates blood lactate removal. McArdle et al. (24) also point out that intermittent
or interval training requires a different approach to recovery because the exercise is performed at a very high intensity over a very short duration using only the immediate (ATP-PCr) energy system, enabling a subsequent bout of heavy exercise to begin, following a brief recovery.

Overtraining is usually conceptualized strictly in terms of the volume of training, yet overtraining might also be expressed as under-recovering. If the recovery rate can be improved, greater training volumes could be possible without sustaining negative effects of overtraining (6). Improved recovery may result in establishment of a higher performance plateau (1,6). Overtraining is then, the simultaneous product of both the recovery and the work-out. The answer to overtraining rests in either reducing the workload during training, or perhaps, in improving the quality of recovery (6). For the purposes of this paper, we will use Bishop et al.’s (6) definition of recovery, the ability to meet or exceed prior recent performance in a specific activity.

MODALITIES

A multitude of modalities have been used for the treatment of both acute and chronic athletic injuries. Several of these modalities have been adapted for use as recovery aids immediately post performance or at other times between sessions. These modalities include: water immersion, cryotherapy, thermotherapy, contrast therapy, massage, ultrasound, compression garments, active recovery, stretching and electrical muscle stimulation (EMS). The purpose of this paper was to review the practicality and effectiveness of the modalities thought to decrease time to recovery and increase performance after recovery, specifically in aerobic athletes.
Water Immersion

When a body is immersed in water, the compressive force of hydrostatic pressure is placed on the submerged portion in proportion to depth of submersion. This pressure can cause the displacement of body fluids from the extremities towards the thorax. The displacement of fluid may enhance the mobilization of substrates from the muscles, increase cardiac output, reduce peripheral resistance as well as increase the body’s ability to transport substrates. For every 1 cm depth of immersion, the hydrostatic pressure increases by 0.74mm Hg. The proportional change in hydrostatic pressure with depth on a head-up vertically-oriented causes an upward squeezing action on the body, which at a 1m depth (74mm Hg) is almost equal to normal diastolic blood pressure (80mm Hg) (41).

Because water is essentially non-compressible, it occupies the same volume regardless of pressure whereas the body is made up of various elements including gasses whose volumes change according to pressures that act on them. When external pressure on the body increases, gases and fluids are displaced to lower-pressure areas. It is this movement that might improve the athlete’s ability to recover from exercise as a decrease in transportation time could increase clearance of waste products. In the case of injuries, an increase in the pressure gradient, caused by hydrostatic pressure, between the interstitial compartment of the legs and the intravascular space should reduce edema similar to compression stockings. Edema in response to exercise or muscle damage may increase both the transport distance and compression of localized capillaries, reducing oxygen delivery to localized cells. With excessive muscle edema, such an increase in transportation time could cause an increase in cellular damage or cell death.
Also, a positively increased pressure gradient could reduce cellular infiltration by leukocytes and monocytes decreasing further tissue degeneration. Reduction in muscular inflammation may improve contractile function as well as lower the levels of inflammatory cells and muscle enzymes circulating in the blood. Reducing edema may, therefore, decrease ongoing secondary hypoxic injury to the tissues, which in turn may decrease the time to recovery following muscle damaging exercise (33,41).

Buoyancy reduces the gravitational forces that act on the musculoskeletal system, perhaps allowing for more relaxation of gravitational muscles and energy conservation. Greater relaxation is thought to reduce perceived fatigue (41). Wilcock et al. (41) suggest that the decrease in the perception of fatigue post-exercise may also be due to reduced neuromuscular responses during water immersion.

The predominant effect of water immersion and the associated increase in central blood volume expansion is an increase in cardiac pre-load. Increasing the depth of immersion causes greater stroke volume, leading to increased cardiac output (41). Wilcock et al. (41) noted that when immersed in thermoneutral water to the level of the hips, heart rate tends to decrease by 4-6%, with an 11-18% reduction when immersed to the level of the xiphoid process, and a 3-15% reduction when immersed to the level of the neck. An increase in stroke volume causes an increase in mean arterial pressure, thus causing arterial baroreceptors to slow the heart in order to prevent abnormally high blood pressure levels (41).

There are no articles that support or refute the observations and suggestions proposed by Wilcock et al. (41). While this therapy is relatively inexpensive and can be applied as long and
as often as the athlete or coach desires, it may not always be conveniently available. Overall, this modality appears to be time and cost effective while offering a multitude of possible benefits regarding recovery particularly of endurance athletes. The lack of support from research suggests that further investigation immersion is warranted before accepting this modality as an effective post exercise recovery therapy.

Cryotherapy

Cryotherapy results in conductive heat loss and may assist other body mechanisms in reducing muscle temperature. Some researchers (37,21,25,30,32,42) suggest that no effect is evident during the first three minutes of cryotherapy. Deep-muscle temperature gradually decreases for several minutes immediately after removing cryotherapy, while superficial muscle temperature begins to increase (37).

Cooler water temperatures are reported to have some effect on the physiological responses of the body. During head out immersion, as water temperature decreases, heart rate slows, decreasing cardiac output. Arterial blood pressure and peripheral resistance also increase as blood is redirected from the periphery to reduce heat loss to maintain core temperature. Oxygen consumption and metabolism also increase to assist in maintaining core temperature. Vasoconstriction takes place reducing fluid diffusion into the interstitial space. This reduced fluid diffusion can assist in reducing acute inflammation from muscle damage. This in turn can reduce pain, swelling and the loss of force generation that is also associated with inflammation (24,33,41). Cooling of tissue decreases the rate of transmission along neurons by decreasing the rate of production of acetylcholine and possibly stimulates superficial inhibitory cells that
regulate the impulse of pain perception to the Central Nervous System. Reduction of nerve impulse transmission by cold has two effects: 1) reduced level of pain perception (analgesia); and 2) reduction in muscle spasm. While reduction in pain may be of benefit, a decline in neural transmission may reduce muscular contractile speed and force-generating ability of an athlete post-application (33,41).

Jutte et al. (18) examined the specific relationship between skin temperature and intramuscular (IM) temperature (measured 2cm below subcutaneous adipose tissue) and described the relationships between muscle temperature during icing and the combination of skin temperature, room temperature, body core temperature and subcutaneous adipose thickness. Results of the study were that intramuscular (IM) temperatures declined in a pattern that was typical with 30 minutes of ice bag therapy. During the course of the cold treatment, IM temperature declined just over 8° C, whereas skin temperature declined approximately 27° C. Core temperature also declined slightly (2° C) (18). Jutte et al. (18) point out that the skin temperature begins to warm immediately after removing the cold, whereas IM temperature continues to fall for several minutes. IM temperature continued to fall for approximately 6 minutes after the 30 minute cryotherapy application and never warmed back to, nor did IM temperature exceed its baseline temperature in the 120 minutes it was measured post treatment. Time, rather than skin temperature or adipose thickness proved to be a better predictor of IM temperature over the duration of cryotherapy treatment. The difference in cooling and rewarming times could be a result of the depth of the tissue to be cooled or may be due to the differences in tissue density and the degree to which each is hydrated between the skin, adipose, and muscle tissue (18).
Long et al. (21) noted that time to cool tissue (using ice bags) to 10° C below pre-exercise resting temperature at both one and two cm depths was longer in tissues that underwent a no-exercise treatment. Long et al. also noted that the time required to cool tissue to pre-exercise resting temperature took up to 54 minutes longer with no ice application than with the ice bag application. One and two cm depths were cooled to pre-exercise baseline temperature within seven minutes when the ice bag was used. Thus, it was concluded that following exercise, intramuscular temperature decreases to 10° C below pre-exercise temperature more rapidly compared to intramuscular temperature cooling with no prior exercise. Simply stated, muscles stimulated by exercise can cool faster (21).

Merrick et al. (25) compared the cooling efficacies of several commonly used forms of cryotherapy: bags of crushed ice (ice), commercially available ice packs with a terrycloth panel that allows the melting ice from the pack to come in contact with the skin providing the opportunity for evaporative cooling and heat transfer via a wet interface (wet ice), and commercially available frozen gel packs (Flex-i-Cold). All forms of cryotherapy were applied to a 6x6cm area on the anterior thigh at a pressure of 45mmHg by elastic wraps in order to hold each therapeutic modality in place. The controls (between treatments in repeated measures) received neither cryotherapy nor compression. Four thermocouples (2 surface and 2 implantable) were placed in 2x2cm grid at the center of the 6x6cm area. The two surface thermocouples were fixed to the skin surface, while the two implantable thermocouples were inserted to depths of 1 and 2cm subadipose. Insertion depths were calculated relative to adipose thickness. Instantaneous temperature measurements were taken at 30-second intervals for the duration of the experimental period (32 minutes). Subjects rested in a supine position for 3
minutes before the experimental treatment while baseline temperatures were recorded. At the end of the 2-minute baseline period, 1 of the 4 experimental treatments was applied for 30 minutes. Subsequent treatment sessions were spaced a minimum of 48 hours apart. All three cryotherapy treatments were applied with similar compression pressures (25). Baseline temperatures did not differ across treatments.

At the skin surface, the Flex-i-Cold treatment produced its coldest temperature at roughly one third of the way through the treatment, whereas the ice and Wet-Ice treatments were coldest within 60 seconds of the end of the treatment. At all measurement depths, the control temperatures were coldest within the first minute of measurement. The 2 ice-based treatments produced cooler temperatures than did the gel pack. The results of the ice-bag and Wet-Ice treatments were not significantly different (25).

At the 1cm sub-adipose depth, all three cold treatments produced cooler temperatures than did the control. The ice-based treatments also produced colder temperatures than did the frozen gel pack. There was no difference between the ice-bag and the Wet-Ice treatments. At the 2-cm sub-adipose depth all three cold treatments produced cooler temperatures than did the control, however, there was no difference between the three cold treatments (25). Merrick et al. (25) point out that it is quite likely that they did not cool the tissues long enough to be able to determine if there was truly a difference between the different cold modalities at the deeper 2-cm sub-adipose depth. Potentially, this difference may even become apparent with continued temperature measurement after removal of the cold modality following a 30-minute application because deep temperatures typically continue to fall for several minutes after application (25). Merrick et al. (25) concluded that it appeared that some thermodynamic properties have larger
effects on IM temperature than others. Among the most important of these is the effect of a change of physical state. Ice-based modalities go through a change of state from solid to liquid and as a result absorb substantially more heat. This increased heat absorption resulted in colder IM temperatures at the 1 cm sub-adipose depth than were observed with gel packs (25).

In contrast to Jutte et al. (18), Otte et al. (32) observed that as the thickness of adipose tissue increases, the cryotherapy treatment duration required to decrease IM temperature by a standard amount (7° C) increased dramatically. Otte et al. suggested that the current clinical practice of applying cold for 10 to 30 minutes is only adequate for relatively lean patients and is not at all adequate for patients with skinfolds exceeding 20 mm. It was also suggested that skinfold thickness be used as a guide when determining cryotherapy duration (32).

Zemke et al. (42) investigated the intramuscular temperature responses of the calf musculature to one of two modes of cryotherapy delivery. The hypotheses were that ice massage would provide a lower intramuscular temperature than an ice bag applied with pressure; ice massage would provide a more rapid decrease in intramuscular temperature than an ice bag alone; ice massage would provide a longer period of intramuscular temperature depression than ice bag; and that subcutaneous fat at the testing site would play a significant role in the insulation of the musculature at the testing site (42).

The results of the study suggested that there was no difference between ice massage and ice bag when reduction of intramuscular temperature was the treatment goal. The data also suggested that the duration of the lowest temperature did not differ between ice bag and ice massage as well as showing no difference in the maximum change in temperature between cryotherapy
modes. Finally, there were no strong correlations between subcutaneous fat and lowest
temperature, time to lowest temperature, duration of lowest temperature, or change in
temperatures regardless of treatment mode (42). Therefore, the results of the study by Zemke et
al. (42) contradict those of Otte et al. (32). However, Zemke et al. (42) suggested that when rapid
cooling is needed, as in acute muscular trauma, ice massage appeared to provide a faster
intramuscular cooling rate than an ice bag, as intramuscular temperature reached its lowest point
an average of 10.5 minutes earlier during the ice massage treatment (17.9 minutes) than during
the ice bag treatment (28.2 minutes). Zemke et al. (42) also pointed out that the reason for this
time difference could be attributed to the difference in treatment surface area of contact, in that
the surface irregularities of an ice bag may influence the lowest temperature or the change in
temperature measurements, whereas the smooth surface consistent with ice massage may allow a
larger surface area of the treatment area to come in contact with a greater surface area of the
treatment modality, thus promoting greater cooling effects via increased heat loss from
conduction.

Myrer et al. (30) stated that there is indication that significant intramuscular temperature
decreases can be accomplished with either crushed-ice packs or cold whirlpool. It may be,
however, that the sustained temperature reductions brought about by the cold whirlpool, after the
treatment is concluded, are more effective than ice packs in preventing secondary hypoxic injury
that may resume with rewarming, assuming that secondary hypoxic injury hinders recovery from
exercise (3,29,30). Bosak (6) observed that cold water immersion slightly improved recovery,
thus decreasing the rate of decline of next day 5K performance (8).
In a baseball investigation by Verducci (37), in which interval cryotherapy and a mild warming treatment were used, five of six pitchers indicated they had less arm soreness the next day with interval cryotherapy between innings during pitching. Six of 10 participants reported less soreness. The participants in both treatments performed more work than without cryotherapy applied during their interval training session. Verducci (37) concluded that the three-minute icing with 4.5 minutes of rewarming may have brought the temperature closer to the optimal work temperature. The direct application of interval cryotherapy to weight training still needs to be examined (37).

Vaile et al. (36) found that cold water immersion performed between two high-intensity exercise tasks helped to maintain repeat performance in hot environmental conditions compared with active recovery and concluded that the use of cold water immersion is supported in various sports at times when two training sessions a day may be performed in hot environmental conditions, and during prolonged competitions. Although they did not observe a significant performance enhancement, the maintenance of performance during maximal efforts separated by only one hour may be crucial in many sports (36).

The conclusions made by Zemke et al. (42) that ice massage decreases intramuscular temperature faster than the ice bag because of increased treatment surface contact between the skin and the modality, would also apply to cold whirlpool therapy. Increasing the surface area of contact would be vastly increased if the entire extremity is submerged in water of equal temperature to ice bag application. Cold whirlpool therapy also increases conduction and convection properties of heat removal from the portion of the body that is exposed as suggested by Merrick et al. (25) in their study of wet-ice and ice bag therapy and by Myrer et al. (30) in the study of ice bag
therapy and cold whirlpool therapy. While cold whirlpool therapy may be more efficient at cooling a large surface area, it faces the same negative ramifications as water immersion therapy such as: Ice bag use may be more cost-effective because it requires only Ice and plastic bags, much less space is required in order to apply ice bag treatments, and the treatment is more time efficient in that the athlete can move on to other activities if the ice is wrapped onto the extremity (25,29,32,42). However, there is no definitive evidence that any cryotherapy speeds recovery.

Thermotherapy

An increase in superficial tissue temperature over short durations causes peripheral vasodilation thus increasing cutaneous blood flow. Heart rate also increases in response to hot water immersion. This increase in heart rate may reduce stroke volume due to lack of cardiac filling time, but overall cardiac output increases compared with thermoneutral immersion. The increase in cardiac output and a lower peripheral resistance allows an increase in subcutaneous and cutaneous blood flow. This increases the permeability of cellular, lymphatic and capillary vessels. Increased permeability increases metabolism, nutrient delivery and waste removal from the cells that can increase healing. However, for short-duration superficial application, these changes are not likely to occur within the muscle, but rather only in the skin. Also, blood flow through the muscle may decrease compared with thermoneutral immersion. Lower water temperatures may then have greater benefits than hot or thermoneutral in substrate transportation within a muscle (41).

Wilcock et al. (41) notes that, physiologically speaking, hydrostatic pressure, rather than water immersion temperature, would seem the mechanism that could benefit exercise recovery.
Ultimately, the aim of the recovery process is to enhance future performance. Increases in blood plasma fraction (movement of interstitial-intravascular) during immersion have been observed to require at least 10 minutes of exposure; therefore, as a possible recovery strategy, immersions should be of at least 10 minutes in duration (41). However, there is no definitive evidence that any form of thermotherapy speeds recovery.

Contrast Therapy

A few studies have seen positive effects on recovery time and performance when combining modalities such as massage and active recovery as opposed to using modalities individually (3). Coffey et al. (12) compared the effectiveness of three different recovery modalities: active, passive and contrast temperature water immersion (submersion of the affected area alternating between hot and cold water for a predetermined time period), on the performance of repeated treadmill running, blood lactate concentration and pH. They hypothesized that both active recovery and contrast temperature water immersion would be more effective in restoring performance, removing lactate and maintaining pH than passive recovery (12). The results indicated that both active recovery and contrast temperature water immersion appeared to be similar in reducing lactate accumulation (39). However, the participants in the contrast therapy water immersion condition had a lower heart rate and reported a lower perception of fatigue, discomfort or stress during recovery (12). Therefore, contrast temperature water immersion may be a better recovery strategy for athletes after high intensity exercise because it appears to have similar effects in reducing blood lactate concentration as active recovery, but the athlete achieves these effects with less exertion and increased perceptions of recovery (12). However, it should also be pointed out that in their study, high intensity treadmill running performance returned to
baseline four hours after the initial exercise bout regardless of the recovery strategy employed. Another point to be considered is that following high intensity exercise, some acute trauma exists in the involved muscles. Introducing these areas to the hot portion of contrast therapy could contribute to excess edema formation, thus causing the associated tissues to suffer secondary hypoxic injury (41).

Contrast therapy has been considered to enhance athletic recovery through: 1) Stimulating area-specific blood flow; 2) Increasing blood lactate removal; 3) Reducing inflammation and edema; 4) Stimulating circulation; 5) Relieving stiffness and pain; 6) increasing range of motion; 7) Reducing delayed onset muscle soreness (33,41). It is suggested that contrast therapy may mimic one of the mechanisms attributed to active recovery without the same energy demands. Alternating vasoconstriction and vasodilation is thought to act in a comparable way to muscle pumping, increasing blood flow and metabolite removal, enhancing recovery.

Wilcock et al. (41) points out that if vaso-pumping does occur during contrast therapy, it would seem unlikely to cause a great effect at such a slow frequency. Another point to consider with vaso-pumping is that intramuscular temperature has not been observed to change with alternating contrasts, only subcutaneous temperature. If temperature does not change at deep tissue levels with alternating immersion, any vaso-pumping would then be likely to occur at only a subcutaneous level. To aid recovery and intramuscular waste removal by vaso-pumping, temperature changes would be required at a deeper tissue level. During high body temperatures, as may occur after intense athletic exertion and hot water immersion, the sudden immersion into cold may cause cutaneous vasodilation rather than vasoconstriction in a shock response (41). Therefore, contrast therapy seems to have little to no impact on recovery that could not be
achieved by combining other, more widely used modalities such as active recovery and cryotherapy. These issues warrant further research on contrast therapy.

Massage

Massage is used in general approaches, such as preparation for competition, between competitions and in assisting recovery from competition. A large part of massage application in sporting events is the product of many coaches’ and athletes’ opinions, based on observations and experiences, that massage can provide several benefits to the body such as increased blood flow, reduced muscle tension and neurological excitability, and an increased sense of well-being.

Weerapong et al. (39) noted that several reviews of the literature have found relatively little support for any physiological effects resulting from various massage techniques on any symptoms of muscle damage or any physiologically related measure thereof. While evidence outlining the efficacy of massage is almost nonexistent, many in the sporting community continue to use it as a recovery modality. It is thought that the effects of massage, if any, are most likely produced by more than one mechanism specifically including biomechanical, physiological, neurological and psychological mechanisms (18). Weerapong et al. (39) point out that the majority of these mechanisms are speculations with little empirical data to support their statements (3,39).

Prentice (33) states that the application of mechanical pressure on the muscle tissue during massage decreases “tissue adhesion”. Increased muscle-tendon compliance is believed to be achieved by mobilizing and elongating previously shortened or adhered connective tissue. Improved muscle compliance supposedly results in a less stiff muscle-tendon unit.
Biomechanically, three main measures are used to assess muscle-tendon unit compliance. These include: dynamic passive stiffness, dynamic active stiffness and static joint end range of motion (3,33,39). Unfortunately, there are a limited number of studies that have investigated these three measures and an even smaller number of studies that found positive effects on these measures following massage treatment. Furthermore, activities such as warm-up and stretching were found to have a much more significant effect on stiffness and range of motion.

Physiologically, massage is thought to cause an increase in skin and muscle temperature. This has been shown by Longworth et al. (22) and Drust et al. (13). While an increase in skin and muscle temperature were observed in both studies, temperatures returned to baseline within 10 minutes. Moreover, both studies failed to elicit an increase in the temperature of muscles deeper than 2.5cm (13,22). Increased muscle blood flow is another physiological response thought to occur with massage treatment, yet there is a lack of evidence confirming this speculation, as research has shown no change in total muscle blood flow (13,22,39).

It has been proposed that massage may affect neuromuscular excitability by decreasing the Hoffman reflex amplitude (H-reflex), thus decreasing muscle tension that may cause pain and spasm (26,27,28). Morelli et al. (27) found that H-reflex amplitude was decreased during the massage treatment, but returned to baseline once treatment ceased. Psychological benefits of massage have been shown in boxers during recovery after matches and training sessions by using the Perceived Recovery scale questionnaire (39). No change in fatigue indicators including blood lactate levels and heart rate were recorded. One caveat is that this recovery scale has not been widely used in research studies and there are no published articles reporting the correlation between the Perceived Recovery scale and physiological markers of fatigue.
Martin et al. (23) compared the effects of sports massage, active recovery, and rest in promoting blood lactate clearance after supramaximal leg exercise culminating in the support of active recovery for the abatement of metabolic acidosis following high-intensity anaerobic exercise. Ten volunteers from a cycling club performed three successive Wingate cycle tests with a very high braking force, as suggested by Bar-Or (4) of 0.090 kp/kg for adult non-athletes and 0.100 kp/kg for adult athletes, with two-minute rest intervals between each to elevate blood lactate levels (4). Each trial was followed immediately by one of three conditions: 20 minutes of pedaling the cycle ergometer at 80 RPMs at an intensity equal to 40% of VO$_2$peak, sports massage 5 minutes per leg in both prone and supine positions, and 20 minutes of rest lying in the supine position. Statistical analysis revealed that 20 minutes of sport massage performed on the involved limbs directly after exercise had no significant effect on blood lactate clearance while 20 minutes of active recovery exercise at 40% VO$_2$peak produced a significant (59%) decrease in blood lactate concentration when compared to sports massage and rest (23).

Weerapong et al. (39), and Martin et al. (23) pointed out that much of the supportive evidence for the positive effects of massage has been based on anecdotal reports, rather than on sound scientific data obtained using modern laboratory equipment and methods.

Another issue is that lactate has long been thought of as a marker of fatigue, resulting in the use of blood lactate concentration post exercise in measuring recovery (15). A study by Gladden et al. (15) reported that when metabolic rate and blood lactate concentration were held constant, a 65% increase in blood flow above baseline had no effect on lactate clearance. Thus, increased blood flow seemed to have had little or no influence on lactate clearance, raising the question of
whether or not blood lactate concentration should even be considered for use as a measure of fatigue or recovery (15,18,23).

Several authors have identified a correlation between pre and or post activity massage and psychological benefits (16,20,22,23,33,39,40). A study by Weinberg et al. (40), utilized the Profile of Mood States questionnaire immediately before and after each trial to measure specific psychological criteria. The study found a relationship between by pre-running massage and increased feelings of wellbeing (27). Investigators determined that increased feelings of wellbeing occurred due to decreases in tension, depression, anger, fatigue, confusion, and anxiety following the pre-run massage (27). The authors suggest that there may be a relationship between increased psychological recovery rate and physiological recovery rate following exercise (27).

Hemmings (16), demonstrated that massage can positively affect acute psychological regeneration by causing a decrease in perception of fatigue following boxing training (16). Hemmings also points out that unlike Weinberg (40), the study did not find a significant difference among depression, anger, and tension subscales. However, the tension subscale probability may have evidenced a type II error due to a small sample size (16).

A decrease in saliva cortisol levels has been shown to indicate increases in parasympathetic activity, which assists in determining mood, and is also thought to occur as a result of massage treatment (39). Leivadi et al. (20) performed massage therapy on a group of dancers for five weeks, measuring saliva cortisol levels after the treatment in the first days and the last days of the treatment period. When compared with a group of dancers that received relaxation therapy
for five weeks, researchers observed that both groups reported less anxiety and depressed mood after their sessions, while the massage group showed a decrease in cortisol levels. This suggests that relaxation therapy may be just as effective as massage therapy in terms of mood (20).

To date, there is no clear evidence that massage can improve performance or enhance recovery. It has been suggested that since even light exercise can cause significant elevations in muscle blood flow. If increased muscle blood flow is deemed beneficial to post-exercise muscle recovery, light exercise may be as, or more, beneficial than massage (35). Massage therapy can be very costly because a certified massage therapist or athletic trainer would be required to apply the treatment. Massage therapy is also time consuming for the athlete, not to mention that in order to apply the therapy, space must be available for use in order to protect the athlete’s privacy.

Ultrasound

It has been suggested that ultrasound may influence post-exercise muscle recovery. Proposed physiological responses to ultrasound include increased blood and lymph flow thus minimizing inflammation-induced damage as well as increasing the histamine response, leading to more rapid tissue repair (35). Wang et al. (38) evaluated the effects of both pulsed and continuous ultrasound on the recovery from muscle fatigue. Fifteen male subjects performed two trials including 60s of maximum isometric contraction followed by 12x5s maximum contractions with 15 to 55s rest between each contraction. Either continuous or pulsed ultrasound was applied during the rest period on one arm and a placebo treatment was applied to the other (38). Peak force was significantly closer to the subjects’ true maximum in the arm treated with continuous
ultrasound whereas there was no significant effect with the pulsed ultrasound treatment (38). However, no studies have been done regarding the physiological effects of ultrasound on post-exercise muscle damage and repair. Ultrasound units are very costly and bulky, thus deterring individuals from purchasing them. Plus, there is no evidence that they provide faster recovery than other more cost-effective modalities.

Compression Garments

There are three types of compression garments: graduated compression stockings worn for the prevention and treatment of deep vein thrombosis, compression sleeves worn over limbs and joints to lend support or reduce swelling, and elastic tights and tops worn as exercise clothing (5). Berry and McMurray (5) noted that when highly fit male college students wore graduated compression stockings during both exercise and recovery they had lower recovery blood lactate concentrations than when wearing the stockings only during exercise or not at all.

Chatard et al. (9) observed that wearing graduated compression stockings during an 80-minute recovery with legs elevated decreased blood lactate concentrations in elderly trained cyclists and significantly increased post-recovery performance compared to a control trial (9). Kraemer et al. (19) saw a significantly smaller increase in plasma creatine kinase concentration when untrained subjects wore compression sleeves for 5 days after they performed eccentric exercise of the elbow flexors aimed at inducing muscle damage. It was also noted that the compression sleeves prevented the loss of elbow range of motion, decreased perceived soreness, reduced swelling and promoted the recovery of force production (19). Another study, employing creatine kinase concentration measures to indicate muscle damage and severity, found that 12 hours of wearing a
lower-body compression garment after a rugby game enhanced recovery from muscle damage when compared with passive recovery, but not when compared with active recovery or contrast therapy (14).

Argus (2) studied the effects of compression garments on performance of repeated sprints and isokinetic hamstring training performed on three consecutive days, both 24 hours apart as well as four days after the initial testing. This study demonstrated that compression garments may produce a small worthwhile positive effect in reducing fatigue in repeated sprints, maximal concentric and eccentric exercise as well as reducing the perception of pain (2). Average sprint time for 12 repetitions of 20 meters improved each session for the compression trials in the initial testing block, while performance decreased during the no-compression trials (2).

Previous studies have pointed out that a greater increase in creatine kinase as well as a greater amount of muscle damage occurred during trials in which no compression garments were worn than during trials in which compression garments were used, likely influencing the decrease in sprint performance as well as influencing pain (10,19). In that same study by Argus (2), researchers observed a significant decrease in pain values with compression garments compared to no compression garments on day seven after recovery from the initial testing block. Improvement above baseline values was observed during the compression trials, while no improvement was observed during the no-compression trials. Four days after the initial testing block, concentric work for both treatments had not returned to baseline. Eccentrically, the individuals wearing compression garments returned to baseline levels four days after the initial block while the subjects not wearing compression garments had not returned to baseline (2). This evidence suggests that compression garments may be responsible for a small benefit to
speeding recovery over consecutive days, however their benefits may be outweighed by their cost.

Active Recovery

According to Barnett (3), active recovery is most commonly associated with increasing the rate of lactate clearance. However, the lactate removal rate does not appear to be a valid indicator of recovery quality, nor does an increase in blood flow effect lactate clearance (23). Gill et al. (14) noted that compared to passive recovery, rates of recovery were significantly faster in rugby players post game when players engaged in active recovery, contrast temperature water immersion therapy, or wore lower body compression garments. Rugby players sustain repeated blows to tissues by direct contact which could elicit the same or similar levels of muscle damage as very intense aerobic exercise (14).

Coffey et al. (12) studied well trained male runners using three modalities similar to those used in the study by Gill et al. (14) including: active recovery (40% of perceived recovery), passive recovery and contrast temperature water immersion (participants moved between 60s cold and 120s hot water baths. All modalities were applied for 15 minutes following the treadmill exercise bouts. No significant differences between the modalities on performance following 4 hours of recovery were observed, thus suggesting that the post exercise warm-down may not provide any significant benefits to athletes (34).

Other researchers question whether or not active recovery between sessions inhibits the rate of glycogen store replenishment. Of the studies investigating this, results have shown either an increase in the rate of glycogen resynthesis or no difference in glycogen re-synthesis between
active and passive recovery (3,14,34). Additional research is needed to determine if active recovery has any bearing on glycogen resynthesis and ultimately rate of recovery.

Stretching

Like massage, stretching is likely one of the oldest modalities used in attempt to decrease time to recovery. Stretching has been shown to increase joint range of motion (3). No research has been published evaluating the effect of stretching between exercise sessions on performance following recovery. However, a reduction in explosive power has been observed in pre-exercise stretching for up to 60 minutes prior to performance (17,31). In 2002, Jones found an inverse relationship between flexibility and running economy, suggesting that there was little benefit in stretching prior to running activities (7). Bobbert et al. (7) have suggested that stretching may disperse accumulated edema resulting from muscle damage incurred during exercise (11). Stretching may reduce or slow the inflammation process and mitigating further damage, but, this has not yet been investigated (3). There is no definitive evidence that stretching speeds recovery.

Electrical Muscle Stimulation

Electrical muscle stimulation has been used to activate contractions in specific muscle fibers in order to remove edema from the damaged area via the “muscle pump”. There is little evidence that it decreases time to recovery or improves performance following the treatment and recovery period, neither does transcutaneous nerve stimulation cause an analgesic affect on pain consequent to muscle damage following exercise (3). There is no definitive evidence that electrical stimulation speeds recovery.
DISCUSSION

Whereas there are many modalities used in sports medicine for treatment of acute and chronic injuries, there is only scant evidence that a few of these may be beneficial to uninjured athletes hoping to reduce recovery time and enhance performance post-recovery. The bulk of the recovery modality research has been the investigation of the effect of decreasing muscle temperatures in order to avoid further damage by the inflammatory response, as well as the application of heat in an attempt to enhance blood flow in the hope of more rapidly moving harmful by-products out of the damaged areas.

There is evidence suggesting that water immersion, no matter the temperature, has significant effects on recovery and performance as a result of the pressure gradient created inside the extremities, muscle fibers, interstitial spaces, arteries and veins. Significant increases in recovery and performance are also seen in cold water or ice water immersion, but it is unclear as to whether cold has an additive effect to the benefits of water pressure.

Contrast therapy began as a modality to enhance the “muscle pump” in order to rid the damaged area of harmful byproducts. After much debate, it appears that the duration of extremity submersion in either temperature is not long enough to effectively cool or heat the muscles, ultimately failing to impact circulation. However, contrast therapy has been linked to an increased “feeling” of recovery which may be just as effective as actual structural recovery.

Beyond these modalities, there is much more research to be done. First, in order to accurately follow recovery, researchers must identify physiological changes signifying recovery that can be measured. Finally, there are a multitude of modality combinations that have yet to be
investigated that could possibly produce additive effects and further enhance recovery as well as performance.
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CHAPTER 2

5KM PERFORMANCE AFTER 48, 72, AND 96 HOURS OF RECOVERY IN MASTERS RUNNERS

ABSTRACT

Increased running performance can result from either increasing the workload during training, or by improving the quality of recovery. If recovery rate can be improved, greater training volumes would be possible without sustaining negative effects of overtraining. Masters Athletes are middle-aged and older subjects whose recovery may be different from younger athletes. The aim of this study was to determine the amount of time necessary for 10 masters runners (5 male, 5 female) to make a full recovery from an all-out 5K run. The mean age was 51.8 years for males, and 45.8 years for females. Participants completed four 5km time trials (TT), counterbalanced and separated by baseline, 48, 72, and 96 hours of passive recovery. Run time, average heart rate, rating of perceived exertion, and perceived recovery from the previous TT were recorded. Repeated measures analysis of variance found no significant differences between baseline (1486.9secs ± 216.2secs), TT48(1478.1secs ± 201.9secs), and TT72(1458.5secs ± 190.94secs). However, a significantly faster mean run time (p=0.012) was observed for TT96(1451.80secs ± 196.6secs). Some Masters runners (30% in our study) may be able to fully recover in as little as 96 hours of passive rest, while most will take longer than 48 hours to reach full recovery (only
10% of our runners improved after TT48). Ultimately, the amount of rest needed by Masters Athletes to fully recover from an all-out 5 km appears individualistic.

Key words: aerobic exercise, passive rest, endurance runners, training, aging athletes
INTRODUCTION

Recovery from exercise training, the time required for trained athletes to fully recover from an exhaustive bout of activity, has not been widely studied. Bishop et al. (3) defined recovery as the ability to meet or exceed prior recent performance in a specific activity. Overtraining is usually thought of strictly in terms of training, yet overtraining might also be expressed as under-recovery. Overtraining is the simultaneous product of both the recovery and the work-out. The answer to overtraining rests in either reducing the workload during training, or perhaps, in improving the quality of recovery (3). If the recovery rate can be improved, greater training volumes would be possible without sustaining negative effects of overtraining. Improved recovery may result in establishment of a higher performance plateau (1,3).

As our population ages, there is an increasing number of “Masters” athletes. Shephard et al. (8) defined Masters athletes as middle-aged and older subjects who practice substantial and well-documented types and amounts of physical activity. Surprisingly, there is little research available regarding this group of individuals. In a resistance training recovery study conducted in our lab, McLester et al. (6) found that group performance was significantly lower after 24 hrs of recovery in three groups (3 sets to failure in 10 men ages 18-30, 7 sets to failure in 10 men ages 18-30, and 3 sets in 10 men ages 50-65). At 48 hours, performance of the groups was not significantly different from baseline, suggesting that full recovery had been reached in all three groups. Results of this study suggest that there is no difference in recovery time and performance among age groups regarding recovery from strength training. However, McLester et al. (6) noted a great deal of individual variability, specifically following 48 and 72 hours of recovery. Suggesting that regardless of the outcome of the group, each individual reacts
differently to different recovery times. Whereas there are a variety of studies regarding recovery in young adults, there is no research available regarding the amount of time required for Master’s runners to make a full recovery from an all-out 5K run \((1,3,4,5,6,9)\). The aim of this study was to determine the amount of time that is necessary for a Masters runner to make a full recovery from an all-out 5K run. We hypothesized that more time would be needed for Master’s athletes to achieve complete recovery than in published studies of trained runners younger than 40 years of age.

METHODS

Experimental Approach to the Problem

In general the methods reported by Bosak et al. \((4)\) were used for this study.

Subjects

Participants for the study were well trained male \((n=5)\) and female \((n=5)\) runners currently engaged in rigorous training. The participants were between the ages of 40 and 65 years. To obtain participants, runners from the local road running and track club as well as local triathlon competitors were recruited. To be included in this study, the participants must have:

- Been currently involved in a distance running training program,
- Been a male runner who had previously run under 30 min or a female runner who had previously run under 34 min for a 5km distance,
- Been currently averaging at least 15-25 running miles per week,
- Previously completed 5km road or track races,
• Provided sufficient data (from running history questionnaire, PAR-Q, and HRQ) indicating that their health status that allowed them to safely participate in the study, and
• Presented no history of hypertension, orthopedic pathology or the use of drugs prescribed to treat angina, hypertension or any form of cardiopulmonary disease.

Recruitment of participants included completing a questionnaire regarding their running background, racing history, and current training (i.e. weekly or monthly mileage). All participants participated on a voluntary basis. Prior to participation, participants signed a written informed consent.

Procedures

After providing informed consent and completing initial screening questionnaires, participants were given instructions regarding exercise trials. Participants were assessed for age, height, body weight, and body fat percentage using a 3-site skinfold technique (7). Participants then completed a graded exercise test to exhaustion lasting about 10-18 minutes. Ratings of Perceived Exertion (RPE) and heart rate (HR) were collected every minute.

All laboratory tests were completed on a motorized treadmill (Quinton 640, Seattle). The test began with a 2-minute warm-up at 2.5 mph. At 2 minutes, the speed was increased to 5 mph for 2 minutes, followed by 2 minutes at 6 mph, 2 minutes at 7 mph, and 2 minutes at 7.5 mph. At this point, incline was increased by two percent every two minutes thereafter until the participant reached volitional exhaustion. Once the participant reached volitional exhaustion, they were instructed to cool down, while continuing to run at a low intensity for a self-imposed duration that allowed them to recover acutely from testing.
Approximately five days later, participants completed their first 5km time trial (TT). Environmental conditions for each performance trial were recorded. Temperature, heat index and time of day were consistent throughout the study (WBGT= 21.7°C ± 0.94°C, dry bulb temperature = 25.3°C ± 7.5°C, humidity = 68.2% ± 21.3%, heat index = 25.9°C ± 4.0°C). All TTs were completed on a flat, hard surfaced 0.73 mile loop.

Prior to each trial, participants completed a questionnaire just before and after a 1.5-mile warm-up run, regarding their feelings of fatigue and soreness within the quadriceps, hamstrings and gastrocnemius muscle groups. Feelings of muscle fatigue and soreness in the lower half of the body were averaged and rated as a separate group. The same procedure was employed in rating the fifth muscle group which took into account feelings of fatigue and soreness in all muscles and was labeled total body. These questionnaires were based on a visual analog scale with 10cm lines where participants placed an “X” on the line indicating their answer. The ends of the scale were anchored at the low end with “no soreness or fatigue”; “completely recovered” and at the high end with “extremely sore and very fatigued”; “not at all recovered” (i.e. lower scores were always more favorable). The subjective questionnaires were used to evaluate the participant’s perceived recovery status (PRS) before the warm-up portion of every TT in order to determine whether or not feelings of fatigue remained consistent prior to each TT.

Subjects performed a 1.5-mile warm-up prior to each 5km TT. In a counterbalanced order, participants completed two TTs, separated by 48 hours of passive recovery, 72 hours of passive recovery, and 96 hours of passive recovery. The first TT, prior to any recovery (48, 72 or 96 hours), was considered to be baseline (BL) for that subject.
In order to determine whether or not the effort was consistent for each TT, HR and RPE were recorded during each lap. Following each TT, average heart rate (HR_{ave}), RPE for the overall session (RPE_{session}), and perceived recovery (PRS) from the previous trial were recorded. All runners ran with runners of similar ability to simulate race day and hard training conditions, including verbal encouragement provided often and equally to each participant. At the end of each TT, participants were instructed to complete a low intensity 1.5-mile cool-down to facilitate recovery. All aspects of TTs required approximately 60 minutes for completion.

**Statistical Analysis**

Basic descriptive statistics were computed along with Repeated Measures Analysis of Variance (ANOVA) for making comparisons among mean time trials’ finishing times, HR_{ave}, RPE_{session}, and PRS. Mean finishing time ($T_{ave}$) and mean time change ($\Delta T$) between the baseline TT (BL) and the TT following 48 hrs of passive recovery (TT48) were compared to $T_{ave}$ and $\Delta T$ between the BL and the TT following 72 hrs of passive recovery (TT72) as well as $T_{ave}$ and $\Delta T$ between BL and the TT following 96 hrs of passive recovery (TT96). These 5km performance trials were performed in combination with another study involving 5km trials that included doses of vitamins E and C, ingestion of a protein – carbohydrate beverage and 10 minutes of ice water immersion at thigh level (TT24Recov). As such, repeated measures ANCOVA analyses were performed to rule out possible interference by a previous TT24Recov, by comparing the baseline TT with the Recovery TT, using number of hours from TT24Recov to the current Recovery TT as the co-variate.
All statistical comparisons were made at an a priori p ≤ 0.05 level of significance. Data were expressed as group mean ± standard deviation (SD) and as individual results ± SD.

For individual analysis, a level of least significant difference was calculated from the BL T\textsubscript{ave}. This least significant difference was utilized in determining the ΔT in seconds (positive or negative) a subsequent TT (TT48, TT72 or TT96) must be over or under the TT being compared to quantify as a “response”. That is, any respondent whose TT time deviated over or under the value of the least significant difference, based on the mean SD of the time difference between BL and TT48, TT72 and TT96 using a power of 0.8 and an a priori p ≤ 0.05 significance level for a two tailed paired t-test, was considered a responder. This analysis allowed, participants to be identified as non-responders, positive-responders, and negative-responders.

RESULTS

See Table 1 for descriptive characteristics (5 males) (5 females). See Table 2 for mean finishing times (T\textsubscript{ave}), HR\textsubscript{ave}, RPE\textsubscript{session} and PRS for BL, TT48, TT72 and TT96. No significant differences (p = > 0.05) in BL T\textsubscript{ave} were recorded among comparison of performance trials of TT48 and TT72. TT96 was significantly faster (p = 0.012) compared to BL.

Regarding HR\textsubscript{ave}, no significant differences were found between BL and TT72 (171 ± 12 b/min; p = 0.23) or TT96 where (171 ± 9 b/min; p = 0.25). However, a significantly faster (p=0.007) HR\textsubscript{ave} was observed during BL (173.48 ± 11.48 b/min) than during TT48 (169.83 ± 12.39 b/min). RPE\textsubscript{session}, was significantly lower during BL (8.2 ± 1.06; p= .02) than during TT48 (8.88 ± 0.84) or TT 72 (9.05 ± 0.69), while no significant difference (p = 0.250) was found for TT96.
Regarding scores on the PRS, there were significantly lower perceived recovery scores between BL and TT48 (7.65 ± 2.29, p=0.03) and TT72 trials (7.60 ± 1.90, p=0.04), but not between pre warm-up and post warm-up questionnaires (p = 0.91).

See Table 3 for an illustration of the mean time difference (ΔT) and mean heart rate difference (ΔHR) across trials. There were no significant differences (p = > 0.05) in ΔT between BL, TT48 and TT72. However a significant difference was found for TT96 (p = 0.012). However, ΔHR was significantly higher (p = 0.007) during BL than during TT48 (ΔHR = 3.85 ± 3.03 b/min).

To analyze individual data, a least significance difference was calculated using the mean standard deviation of ΔT between TT48, TT72 and TT96. Positive and negative responders were identified when ΔT between BL and TT48, TT72 and TT96 trials were greater than 60.7 seconds. Positive responders were defined as individuals whose subsequent TT time improved (expressed as a decreased time) relative to BL, negative responders were defined as individuals whose subsequent TT time slowed (expressed as a positive value), while non-responders were defined as individuals whose difference in TT times remained within ± 60.7 seconds of one another. Table 3 shows ΔT among individual BL, TT48, TT72 and TT96 performance trials.

None of our participants responded negatively to 48 hours of passive rest. One individual responded positively to 48 hours of passive rest by running a mean 73 ± 0.00 seconds faster. Nine individuals were considered non-responders to 48 hours of passive rest with a mean time change of 1.67 ± 23.2 seconds. See Figure 1 for a display of positive, negative and non-responders during TT48.
As displayed in Figure 1, none of our participants responded negatively to 72 hours of passive rest. Two individuals responded positively to 72 hours of passive rest by running a mean 107.5 ± 19.1 seconds faster. Eight individuals were considered non-responders to 72 hours of passive rest with a mean time change of 8.6 ± 29.9 seconds.

As displayed in Figure 1, two individuals responded negatively to 96 hours of passive rest by running a mean 156.0 ± 127.28 seconds slower. Three individuals responded positively to 96 hours of passive rest by running a mean 84.3 ± 16.07 seconds faster. Five non-responders were observed in TT96, with a 29.8 ± 26.71 second time difference from baseline.

It is important to note that only one individual (participant 7) was listed as a positive responder during all TTs running a mean time of 95.0 ± 24.25 seconds faster than BL. While there were no runners listed as negative responders during all TTs, runners 5 and 6 were negative responders during TT96 running a mean 156.0 ± 127.28 seconds slower than BL. Both runners 5 and 6 were observed to be non-responders during TT48 and 72. Five individuals (participants 1, 2, 4, 9 and 10) were non-responders in all TTs running a mean time of 12.3 ± 27.49 seconds difference from BL. Participant 7 was a positive responder during all TTs, while runner 3 was a positive responder in only TT72 and TT96, running 95.0 ± 1.41 seconds faster than BL and was a non-responder during TT48 posting a finish of only 12 seconds slower than BL. Participant 8 was a non-responder during TT48 and TT72 posting a mean finish time 43.5 ± 3.54 seconds faster than BL, but was a positive responder during TT96, running a mean finish time 66 seconds faster than BL.
DISCUSSION

The purpose of this study was to determine the amount of time required for Master’s athletes to make a complete functional recovery from an all-out 5 km run. Our analysis found no significant difference between BL and TT48, or TT72, suggesting that all runners were fully recovered following 48 and 72 hours of passive rest. A significantly faster mean run time was observed for TT96 compared to BL (p = 0.12), suggesting that participants had not only fully recovered following 96 hours of passive rest, but responded favorably to the longer rest period.

Whereas there were no group mean significant differences between TTs 48 and 72 for the group, our analyses of individuals by comparison of least significant differences, revealed that 10% of individuals (i.e. one runner) during TT48, 20% of individuals during TT72 and 30% of individuals during TT96 were considered to be positive responders. This finding suggests that 48 hours of passive rest allows for recovery and performance improvement similar to that of 72 hours of passive, but not to the same extent. The same can be said for 72 hours of passive rest when compared to 96 hours of passive rest. Thus, 96 hours of passive rest allowed more participants to improve their performance compared to BL. Our least significant differences comparisons showed that the same individual was a positive responder during all three trials compared to BL. Half of the participants (1, 2, 4, 9 and 10) were non-responders in all trials, while only two individuals were negative responders. Only TT96 was evaluated to have 2 (participants 5 and 6) negative responders.

While, \( \text{HR}_{\text{ave}}^{\text{TT48}} \) was slower than \( \text{HR}_{\text{ave}}^{\text{BL}} \), there was no significant difference when comparing \( \text{HR}_{\text{ave}}^{\text{BL}} \) to \( \text{HR}_{\text{ave}}^{\text{TT72}} \) and \( \text{HR}_{\text{ave}}^{\text{TT96}} \). Since \( \text{HR}_{\text{ave}} \) indicates the intensity at which
an individual is working, this finding suggests that participants did not work at the same level of intensity during TT48 as they did during BL, TT72 and TT96.

RPE$_{session}$ was significantly lower during BL than during TT48 or TT72, while no significant difference was found for TT96. This suggests that while all runners perceived their effort during TT96 to be at the same level as the effort they put fourth during their BL trial, they perceived their effort during TT48 and TT72 to be greater. This further suggests that the increase in our participants perceived exertion during TT48 and TT72 may be due to the fact that their bodies were not sufficiently recovered, therefore they were physically unable to perform at the same intensity level during TT48 (and to a lesser extent, during TT72) as they were during BL and TT96.

All participants began the experimental trials reporting feeling fully recovered prior to BL. However, significant differences in PRS were noted between TT72, TT96 and BL suggesting that individuals in those trials did not perceive the same amount of fatigue during each TT. There were no differences reported among any of the individuals between pre warm-up and post warm-up questionnaires, suggesting that each individual consistently perceived a level of fatigue that was not different prior to the warm-up and the start of each TT.

Masters runners were recovered from an all-out 5 km race on average for all TTs (48, 72 and 96 hours). Most Masters Runners (90% in our study) may be able to fully recover in 48 hours of passive rest, while 10% were able to increase their performance following 48 hours of passive rest. More than half (80%) appeared able to fully recover in just 72 hours (20% were considered positive responders), however, some will take longer than 96 hours to reach full recovery to the
point that they are able to improve their performance (30% of our runners were considered positive responders during TT98). Some runners may require less time to make a full recovery, to the point that more time decreased their performance (20% of participants in our study were negative responders to TT96; 50% were non-responders)). Ultimately, the amount of rest needed by Masters Runners to fully recover from an all-out 5 km appears dependent on the individual.

When investigating 5km performance following 24 hours and 72 hours of passive rest in college age runners, Bosak et al. (4), found that 72 hours of passive rest limited decline in a 2\textsuperscript{nd} 5 km race performance. Surprisingly, although participants in the current study were much older than those in the previous study, our findings are similar; however, Bosak et al. (4) did not evaluate performance following 96 hours of passive rest.

Several limitations were involved in this study and may have contributed to the group’s similar times among TTs. First, this group of runners was recruited from a small community during the warmest months of the year, which severely limited availability of accomplished aging runners as well as those who were willing to participate due to the hot environmental conditions.

Second, the course was different from what participants normally trained on. Due to an inherent “learning curve,” as runners advanced through study trials, they became more familiar with what to expect during the trial and were better able to pace themselves. Third, we were unable to control all aspects of the participant’s lives during the study, leaving key preparation components including diet, preceding daily activities, rest, sleep and hydration; largely up to each participant.

Finally, there was only one-trial at each time point. In order for these results to be considered stable enough for incorporation into training programs by athletes and their coaches, we would want to observe these outcomes repeatedly, over multiple trials for each time point. Furthermore,
it is doubtful that runners would be able to repeatedly drop their performance times by several seconds each time they allow for 72 or 96 hours of passive recovery. On the other hand, this does suggest that most of these runners need 72 hours of recovery before races, if they want to optimize their race times.

One explanation for the $HR_{ave}$BL being significantly higher than $HR_{ave}$TT48 is because of anticipatory tachycardia, due to the idea that our participants may have been unsure of what to expect during the trials. Our course was flat and partially shaded, while most participants reported regularly running courses including hills and majority shade. This anticipation of the unknown has been thought to cause an increase in parasympathetic function, inducing tachycardia in the moments prior to and during the first few of the exercise bout. There is also literature that supports the idea that a "learning curve" exists, and thus causes a hindrance in self-pacing during exercise; in which some characteristics such as running surface, distance, environment and terrain have been altered.

$RPE_{session}$, was significantly lower during BL than during TT48 = or TT 72. This can be explained by evaluating RPE components. It has been suggested that the value reported as RPE is a combination of feedback integration, arising from physiological system responses (i.e. muscular force, HR, ventilation, respiratory rate, oxygen uptake and blood lactate concentration) to formulate a "conscious RPE" and anticipatory forecasting (which forms a "template RPE", against which the conscious RPE is compared) (10). The template RPE is generated using specific environmental and physiological cues to adjust work rate to a level perceived as acceptable. Tucker (10) suggests that these stem from previous experiences and training along with afferent input from the environment including physiological input such as reduced muscle
glycogen stores and increased skin temperature, as well as psychological input including motivation levels, arousal levels and presence of competitors (7). Ultimately, the brain uses the template RPE in order to regulate work rate to ensure that conscious RPE does not increase excessively during any one stage of exercise to avoid premature termination of exercise (7). These concepts are supported by our results.

PRACTICAL APPLICATIONS

For master's runners and their coaches who are interested in reaching peak performance in 5 km racing competition, the procedures of this study may serve as a means for determining the amount of time required for individual athletes or groups of athletes to make a full recovery between intense training sessions and races. This information may be helpful in the individualization of training regimens and periodization cycles of varying durations.
References


APPENDIX

Tables

Table 1  Descriptive Statistics (Males = 5  Females = 5)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
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Table 2  Comparison of BL vs TT48, TT72 and TT96hrs Trials (n=10)

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<th>TT48</th>
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<td>Finish Time (min)</td>
<td>24.78 ± 3.60</td>
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<td>HR&lt;sub&gt;ave&lt;/sub&gt; (b/min)</td>
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<td>*7.6 ± 1.90</td>
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*indicates significant difference vs BL

Table 3  Comparison of BL vs ΔTT48, ΔTT72 and ΔTT96hrs Trials (n=10)

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<tr>
<td>ΔHR (b/min)</td>
<td>3.65 ± 3.29</td>
<td>3.44 ± 4.26</td>
<td>2.53 ± 6.49</td>
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</table>

*indicates significant difference vs BL
Figure 1. Individual 5km run time change (secs) with passive recovery of 48, 72 and 96 hours (counterbalanced order) (n=10). Individuals shown fastest (left) to slowest (right) according to BL finish times.

+indicates positive responder
-indicates negative responder
ABSTRACT

Recovery is viewed as a necessary part of training, allowing adaptations to occur. Training recovery can be defined as the ability to meet or exceed prior recent performance in a specific activity. The aim of this study was to determine the difference in the extent of recovery achieved after a maximal-effort 5K run by 10 Masters runners (5 male, 5 female) after 24 hours of passive recovery with vitamins C and E, protein, and icing therapeutic recovery techniques. The mean age of participants was 51.8 years for males, and 45.8 years for females. Participants performed three time trials (TT), the first served as a baseline (BL), the second and third were separated by either 96 hours (TT96) of passive rest or 24 hours of passive rest along with vitamins C and E, protein, and icing thought to aid recovery (TT24Recov). Repeated measures analysis of variance revealed no significant difference between BL and TT24Recov (p = 0.451) when comparing BL to TT24Recov (1476.5 ± 194.42 seconds), while TT96 was significantly faster than BL (1451.28 ± 196.55 seconds, p = 0.049). Analysis of least significant differences between individuals revealed that 90% of our Masters runners were able to meet our criterion for full recovery with
as little as 24 hours of passive rest when combined with recovery modalities, or 96 hours of passive rest only. These combined modalities appeared to offer more rapid recovery which could lead to increases in training.

Key words: aging runners, aerobic exercise, training, recovery modalities
INTRODUCTION

Many runners incorporate the principle of overload into their training, seeking to maximize training effects. Overload is a positive stressor that can be quantified according to load, repetition, rest and frequency. Recovery is of major importance in the application of the principle of overload. Brooks et al. (7) suggest that recovery is vitally important for obtaining an adaptation and should be applied according to the nature of the desired physiological outcome.

As the US population ages, there is an ever increasing number of “Masters” runners. While there are a variety of studies regarding recovery in young adults (2,4,9,13,19); surprisingly, there is little research available regarding Masters athletes. Despite the fact that physiological responses to stress vary in duration, adaptation to stress requires sufficient recovery. Thus, recovery is viewed as a necessary part of training, allowing adaptations to occur. Training recovery is the ability to meet or exceed prior recent performance in a specific activity (5). Failure to recover adequately can result in injury caused by overtraining. Overtraining is usually thought of strictly in terms of training, yet overtraining might also be expressed as under-recovering. If the recovery rate can be improved, greater training volumes would be possible without sustaining negative effects of overtraining. Improved recovery may result in establishment of a higher performance plateau (2,5). Maximizing the positive benefits of hard training rests in either reducing the workload during training, or perhaps, in improving the quality of recovery (5).

Exhaustive bouts of exercise are known to cause muscle damage which is associated with inflammation, soreness, and ultimately a decrease in performance. Exercise-induced muscle damage is due to biochemical stresses (oxidative stress) and mechanical stresses (contractions)
leading to disruption of the muscle cell membrane and the Z bands of the muscle fibers (8). A plethora of therapeutic techniques including: cryotherapy (icing), non-steroidal anti-inflammatory drugs (analgesics and ibuprofen), and anti-oxidant vitamins (Vitamins A, E, and C), have been hypothesized to decrease the effects of muscle damage and subsequent soreness. While each of these techniques has some scientific basis, their utility in recovery is unknown. Likewise, the majority of the studies involving these techniques measured blood serum markers rather than the individual’s performance. Previous research in our lab by al-Nawaiseh et al. (1) employed these therapeutic techniques with 22 competitive, college-age swimmers using repeated arm Wingate tests. That study showed that the recovery treatments were helpful compared to no treatment in protecting performance level, but did not significantly impact muscle soreness or damage as estimated by creatine kinase levels (1).

There is no literature available regarding the extent of recovery achieved by Masters runners with a combination of passive recovery and therapeutic recovery techniques after all-out exercise. Therefore, the purpose of this study was to determine the difference in the extent of recovery achieved after a maximal-effort 5K run by Masters Runners using 24 hours of passive recovery with a combination of vitamins C and E, protein, and icing therapeutic recovery techniques. We hypothesized that recovery would be better after the use of this combination of recovery techniques.
METHODS

Experimental Approach to the Problem

Methods similar to those used by al-Nawaiseh et al. (1) during a cycling recovery study. In their study, al-Nawaiseh et al. (1) administered oral doses of antioxidants the night before and at least 1 hour prior to the exercise trial. Approximately 30 minutes prior to the exercise trial, participants were given a dose of ibuprofen. Less than 3 minutes following practice sessions, participants drank a protein shake and 3 to 5 minutes following the practice sessions, participants submerged their lower body in ice water for 10 minutes. These methods were chosen in order to aid in the investigation into whether or not the simultaneous use of antioxidant vitamins, amino acids, cryotherapy (cold water immersion), and non-steroidal anti-inflammatory (ibuprofen) could potentially reduce exercise-induced muscle damage, suppress the soreness sensation, attenuate drop in power output, and recover the anaerobic performance ability in short period of time.

Subjects

Participants for this study were well trained male (n=5) and female (n=5) runners currently engaged in rigorous training. The participants were between the ages of 40 and 65 years. To obtain participants, runners from the local road running and track club as well as local triathlon competitors were recruited. To be included in this study, the participants were required to have:

- Been currently involved in a distance running training program, and,
- Been a male runner who had previously run under 30 min or a female runner who had previously run under 34 min for a 5km distance,
• Been currently averaging at least 15-25 running miles per week, and previously completed 5km road or track races, provided sufficient data (from running history questionnaire, PAR-Q, and HRQ) indicating their health status that allowed them to safely participate in the study, and,

• Reported no history of hypertension, orthopedic pathology or the use of drugs prescribed to treat angina, hypertension or any form of cardiopulmonary disease.

Recruitment of participants included completing a short questionnaire regarding their running background, racing history, and current training (i.e. weekly mileage). All participants were volunteers. Prior to participation, participants signed an informed consent for participation in the study.

Procedures

After obtaining informed consent and completing initial screening procedures (questionnaires), participants were given an explanation of the study and instructions regarding exercise trials. Participants were assessed for age, height, body weight; and body fat percentage using a 3-site skinfold technique (15). Participants then completed a graded exercise test to exhaustion (lasting about 10-18 minutes). Ratings of Perceived Exertion (RPE) and heart rate (HR) were collected every minute.

All laboratory tests were completed on a motorized treadmill (Quinton 640, Seattle). The test began with a 2-minute warm-up at 2.5 mph. At two minutes, the speed was increased to 5 mph for 2 minutes, followed by 2 minutes at 6 mph, 2 minutes at 7 mph, and 2 minutes at 7.5 mph. At this point, incline was increased by two percent every two minutes thereafter until the
participant reached volitional exhaustion. Once the participant reached volitional exhaustion, they were instructed to cool down, while continuing to run at a low intensity for a self-imposed duration that they perceived allowed them to recover acutely from testing.

Approximately five days later, participants performed their first 5km performance trial (TT). Environmental conditions for each performance trial were recorded. Temperature, heat index and time of day were consistent throughout the study (WBGT = 21.72°C ± 0.94°C, temperature = 25.3°C ± 7.5°C, humidity = 68.2% ± 21.3%, heat index = 25.9°C ± 4.0°C). All TTs were completed on a flat, hard surfaced 0.73 mile loop. Prior to each TT, participants completed a questionnaire just before and after a 1.5-mile warm-up run, regarding their feelings of fatigue and soreness within the quadriceps, hamstrings and calf muscle groups. Feelings of muscle fatigue and soreness in the lower half of the body were averaged and rated as a separate muscle group. The same procedure was employed in rating the fifth muscle group which took into account feelings of fatigue and soreness in all muscles and was labeled “total body”.

These questionnaires were based on a visual analog scale with 10cm lines where participants placed an “X” on the line indicating their answer. The ends of the scale were anchored at the high end with “no soreness or fatigue”; “completely recovered” and at the low end with “extremely sore and very fatigued”; “not at all recovered”. The subjective questionnaires were used to evaluate the participant’s perceived recovery status (PRS) before and after the warm-up portion of every TT in order to determine whether or not feelings of fatigue remained consistent prior to each TT.
We used the 96-hour recovery data from a previous study (17) including the same individuals for analysis in this evaluation. Those data suggested that full recovery had occurred in all participants by 96 hours. In a similar study investigating time to recovery in college age runners, Bosak et al. noted that 24 hours of passive rest only was not sufficient for recovery following a 5km race, therefore no 24 hour passive rest time trial was included in this study (5).

Participants performed two TTs, the first of which served as the baseline (BL). The TT that followed was separated by 24 hours of passive rest along with a combination of modalities generally thought to aid in recovery (TT24Recov). These modalities included dietary supplementation and application of ice-water immersion to mid-thigh. Dietary supplementation consisted of consumption of over-the-counter supplements including vitamin C and E, and a protein drink. Dietary supplements were administered as follows:

1. Three oral 800 mg doses of vitamin E
2. Three oral 1000 mg doses of vitamin C

Doses were administered directly following the trial previous to the 24 hour passive rest period, with the night time meal during the 24 hour passive rest period, and no less than 30 minutes prior to the TT24Recov TT, while 11 fluid ounces of protein (21.0 g)/carbohydrate (9.0 g) beverage was consumed no more than 3 minutes post exercise. Cryotherapy included 10 minutes of ice water immersion up to mid-thigh of the legs at a water temperature of no more than 15.56 °C (60 °F) and no less than 12.78 °C (55 °F) and was administered no more than 3 minutes post exercise (24).
In order to determine whether or not the effort was consistent for each TT, HR and RPE were recorded during each lap. Following each TT, average heart rate \((HR_{ave})\) and RPE for the overall session \((RPE_{session})\) were recorded. All runners competed with runners of equal ability to simulate race day and hard training conditions, including verbal encouragement provided often and equally to each participant. At the end of each TT, participants were instructed to complete a low intensity 1.5-mile cool-down to facilitate recovery. All aspects of TTs required approximately 60 minutes to complete.

Statistical Analysis:

Basic descriptive statistics were computed along with Repeated Measures Analysis of Variance (ANOVA) for making comparisons among mean time trials’ finishing times, \(HR_{ave}\), \(RPE_{session}\), and PRS. Mean finishing time \((T_{ave})\) and mean time change \(\Delta T\) were compared between each trial. All statistical comparisons were made at an a priori \(p \leq 0.05\) level of significance. Data were expressed as group mean ± standard deviation and individual results ± standard deviation.

For individual analysis, a level of least significant difference was calculated from the BL \(T_{ave}\). This least significant difference was utilized in determining the \(\Delta T\) in seconds (positive or negative) of a subsequent TT (TT24Recov or TT96) must be over or under the TT being compared to quantify as a “response”. That is, any respondent whose TT time deviated over or under the value of the least significant difference, based on the SD for TT24Recov and TT96 using a power of 0.8 and an a priori \(p \leq 0.05\) significance level for a two tailed paired t-test, was considered a responder. This difference allowed participants to be identified as non-responders, positive-responders, and negative-responders.
RESULTS

See Table 1 for descriptive characteristics. See Table 2 for mean finishing times ($T_{ave}$), $HR_{ave}$, $RPE_{session}$ and PRS for BL, TT24Recov and TT96 trials. No significant differences ($p = 0.451$) in $T_{ave}$ were recorded when comparing BL (1486.9 ± 216.29 seconds) to TT24Recov (1476.5 ± 194.42 seconds). However, TT96 (1451.3 ± 196.55 seconds, $p = 0.049$) was significantly faster than BL. Regarding $HR_{ave}$, no significant differences were found between BL, TT24Recov and TT96 (170.3 ± 10.18 b/min, 171 ± 9 b/min, $p = 0.23$). No significant difference in $RPE_{session}$ was reported for BL, TT24Recov or TT96 (8.4 ± 1.68, 8.7 ± 0.79, $p = 0.25$). Perceived recovery scores were significantly lower for BL and TT24Recov than for TT96 trials (6.4 ± 1.88, $p = 0.02$ and 8.45 ± 1.21, $p = 0.04$; respectively), but not between pre warm-up and post warm-up questionnaires ($p = 0.90$).

See Table 3 for an illustration of the mean time difference ($\Delta T$) and mean heart rate difference ($\Delta HR$) across trials. There were no significant differences ($p = > 0.05$) in $\Delta T$ between BL, TT24Recov. However a significant difference was found for TT96 ($p = 0.01$). There was no significant difference in $\Delta HR$ ($p = 0.23$) between BL and TT24Recov or TT96.

To analyze individual data, a least significance difference was calculated using the standard deviation of $\Delta T$ between TT24Recov and TT96. Positive and negative responders were identified when $\Delta T$ compared to BL and TT24Recov and TT96 trials were greater than 113.9 seconds. Positive responders were defined as individuals whose subsequent TT time improved (expressed as a decreased time) relative to BL, negative responders were defined as individuals whose subsequent TT time slowed (expressed as a positive value), while non-responders were defined
as individuals whose difference in TT times remained within ± 113.9 seconds of one another. See Figure 1 for a comparison of non-responders, positive responders, and negative responders.

When analyzing ΔT between individual TTs, it was noted that ΔT of one subject during TT24Recov presented as a positive responder to the TT24Recov treatment. Subject 5 ran a mean 329 seconds faster during TT24Recov than during BL. In contrast, one participant was considered negative responder to the TT24Recov treatment. Subject 1 finished TT24Recov a mean of 166 seconds slower than BL; while eight individuals (2, 3, 4, 6, 7, 8, 9 and 10) did not change their run time sufficiently to be classified as positive or negative responders during TT24Recov when compared to their BL, running a mean of 15.57 ± 49.32 seconds faster.

One individual (participant 6) responded negatively to 96 hours of passive rest by running a mean 246 seconds slower. Following 96 hours of passive rest, there were nine non-responders (participants 1, 2, 3, 4, 5, 7, 8, 9 and 10) with a mean time change of 37.33 ± 15.18 seconds faster than BL. There were no positive responders following 96 hours of passive rest.

Regarding scores on the fatigue, soreness, and recovery questionnaires, the TT96 (8.45 ± 1.21) trials were significantly higher (better) than for TT24Recov (6.4 ± 1.88) and for feelings of recovery (p = 0.005 prior to); however there were no significant differences (p = 0.90) between pre- and post-warm-up questionnaires, suggesting that all runners tended to have the same perceived feeling prior to the warm-up as well as prior to the 5 km TT.
DISCUSSION

In the present study, our aim was to evaluate the impact on 5km performance of a combination of recovery aids in Masters Runners. In general we found that the recovery aids resulted in group mean run times similar to the TT96 trial and not different from baseline. In their study, al-Nawaiseh et al. (1) examined the combined effect of antioxidant vitamins, ibuprofen, cold water submersion and whey protein on short term recovery from high intensity anaerobic cycling the recovery aids were effective in maintaining both absolute and relative mean power. That study also observed that the treatment was successful in aiding the maintenance of performance in subsequent bouts (1).

Bosak et al. (6) investigated 5 km running performance following 24 hours and 72 hours of passive recovery in college age runners and found that following 24 hours of passive recovery, 5 km running performance was significantly slower compared to the baseline performance. It was also noted that there was no significant difference between 72 hours of passive recovery and baseline. Thus, 24 hours of passive recovery alone was not sufficient for full recovery in college age runners. Those findings suggest that our combinations of recovery aids were helpful in maintaining a level of performance, 24 hours after baseline trials, while passive recovery, alone, is not only insufficient for maintaining performance (6).

Whereas there were no group mean significant differences between TTs BL and 24Recov for the group, our analyses of individuals by comparison of least significant differences, revealed that 90% of runners ran similar times during both TT24Recov and TT96 (i.e. less than 18 seconds difference as determined via individual analyses). This supports our group mean analysis, in that
our Masters runners were fully recovered following 24 hours of passive rest plus a combination of recovery modalities as well as after 96 hours of passive rest. Only one (10%) of our Masters runners was considered to be a positive responder during TT24Recov, suggesting 24 hours of passive rest plus a combination of recovery modalities may allow for recovery and performance improvement in a few individuals.

While, $HR_{ave}TT24Recov$ and $HR_{ave}TT96$ were slower than $HR_{ave}BL$, there was no significant group mean difference when comparing $HR_{ave}BL$ to $HR_{ave}TT24Recov$ and $HR_{ave}TT96$. Since $HR_{ave}$ has been linked to intensity with which an individual is working, this finding suggests that participants worked at the same level of intensity during BL as they did during TT24Recov and TT96. No significant differences were found among RPE$_{session}$, suggesting that all runners perceived their effort during each TT to be at the same level as the effort they put forth during their BL trial. This further suggests that while our runners perceived themselves as putting forth the same level of effort during each trial, their bodies may not have been sufficiently recovered, therefore they perceived work at the same level of intensity as harder during TT24Recov than during BL and TT96.

All runners began the experimental trials reporting feeling fully recovered prior to BL, significant differences in PRS were noted between TT24Recov, TT96 and BL suggesting that runners in those trials perceived the same amount of fatigue prior to each TT. There were no differences reported among any of the group means or individual means between pre warm-up and post warm-up questionnaires, suggesting that each individual consistently reported a similar level of fatigue prior to the start of each TT.
These data suggest that Masters Runners were fully recovered from an all-out 5 km race after both 96 hours of passive rest, and after 24 hours of passive rest plus a combination of recovery modalities. Most Masters Runners (90% of our runners did not run substantially slower) may be able to fully recover in as little as 24 hours of rest combined with these recovery modalities, or following 96 hours of passive rest. Twenty-four hours of passive recovery, even when combined with recovery modalities may not be sufficient for masters runners to see an increase in performance (only one runner in our study was a positive responder), but 96 hours of passive recovery, may be too long for a few runners and may even cause a decline in performance below BL (0% in our study were positive responders, and one was a negative responders). Ultimately, the amount of rest needed by Masters Runners to fully recover from an all-out 5 km appears dependent on the individual.

When investigating 5km performance following 24 hours and 72 hours of passive rest in college age runners, Bosak et al. (6), found that 72 hours of passive rest seemed to limit decline in 2nd 5 km race performance. Surprisingly, although participants in the current study were much older than those in the previous study, our findings are similar; however, Bosak et al. (6) did not evaluate performance following 96 hours of passive rest.

Limitations of this study included a "learning curve" specifically for our course, regarding pacing strategies of participants; environmental considerations inherent to aging runners; our lack of control in other aspects of participants' lives beyond the experimental treatments; anxiety of participants due to unknown physiological responses relative to treatments regarding individual performance during the trials; and the fact that these trials were one time performances. While all participants reported being runners who trained regularly, many reported that their training
courses were different from ours in that most runners trained on courses that were mostly shaded and included hills. Our course was completely flat and partially shaded. When considering self-pacing strategies, our participants probably experienced a "learning curve" during all three trials in of this study.

Our study took place during the warmest, most humid months of the year. While conditions were similar during each trial, they did vary slightly and may have affected the performance of our aging runners, specifically those closest to the upper end of the age range.

During our study, we were only able to control a small portion of our participants' daily routines. Our lack of ability to control other aspects vital to performance, including diet, rest and stress levels, may have resulted in hindrances in the performance of some or all of our runners. The majority of our participants reported never having experienced ice water immersion as a modality to facilitate recovery. Along with these reports, there seemed to be a certain level of anxiety that accompanied the unknown physiological responses that would take place in their bodies as a result of the treatment. This anxiety may have played a role on the psyche of the participants during the runs preceding or following the combination of recovery modalities treatment, thus limiting performance. Finally, these trials were performances occurring at one specific point in time and were not repeated at any time during the study could have limited individual performance. Coaches and runners would be well served to repeat these trials multiple times when determining what works best for individual runners.
PRACTICAL APPLICATIONS

These data may be beneficial to coaches and runners desiring to experiment individually with some or all of these recovery techniques. These combined modalities appeared to offer more rapid recovery which could lead to increases in training. This test protocol may also be adapted to different recovery techniques in order to determine what is most beneficial to individual runners regarding maximization of training and recovery. Stable performance results should be required before adopting a particular recovery technique.
References


### Table 1  
**Descriptive Statistics (Males = 5, Females = 5)**

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### Table 2  
**Comparison of BL vs TT24Recov and TT96hrs Trials (n=10)**

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<tr>
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<td>HRave (b/min)</td>
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<tr>
<td>PRS</td>
<td>10 ± 0.00</td>
<td>*6.44 ± 1.89</td>
<td>*8.6 ± 1.17</td>
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</tbody>
</table>

*indicates significant difference vs BL.

### Table 3  
**Comparison of ΔBL vs ΔTT24Recov and ΔTT96hrs Trials (n=10)**

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<th>BL/TT24Recov</th>
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<tr>
<td>ΔT (min)</td>
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<tr>
<td>ΔHR (b/min)</td>
<td>3.23 ± 3.86</td>
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</table>

*indicates significant difference vs BL.
Figure captions

Figure 1. Mean Finishing Time Change (secs) from BL to 24 recovery with therapeutic treatments, and to 96 hours of passive recovery (n=10). Individuals shown fastest (left) to slowest (right) according to BL finish times.

+indicates positive responder
-indicates negative responder
DISCUSSION

The aim of this research was three-fold: 1) to review the practicality and effectiveness of modalities thought to decrease time to recovery and increase performance following recovery, specifically in aerobic athletes 2) to determine the amount of time necessary for Masters Runners fully recover from an all-out 5K run and 3) to determine the difference in the extent of recovery achieved after a maximal-effort 5K run by Masters Runners after 24 hours of passive recovery with vitamins C and E, protein, and icing therapeutic recovery techniques.

A multitude of modalities are used in sports medicine for treatment of acute and chronic injuries. There is only scant evidence that a few of these may be beneficial to uninjured athletes interested in reducing recovery time and enhancing performance post-recovery. The bulk of the recovery modality research has centered upon the effect of decreasing muscle temperatures in order to avoid further damage from the inflammatory response, as well as the application of heat in an attempt to enhance blood flow in hopes of more rapidly moving harmful by-products out of damaged areas.

There is evidence suggesting that water immersion, no matter the temperature, has significant effects on recovery and performance as a result of the pressure gradient created inside the extremities, muscle fibers, interstitial spaces, arteries and veins. Significant increases in recovery and performance are also seen in cold water or ice water immersion, but it is unclear as to whether cold has an additive effect to the benefits of water pressure.
Beyond these modalities, there is much more research to be done. First, in order to accurately follow recovery, researchers must identify physiological changes signifying recovery that can be measured. Finally, there are a multitude of modality combinations that have yet to be investigated that could possibly produce additive effects and further enhance recovery as well as performance.

Second, our goal was to determine the amount of time required for Master’s athletes to make a complete functional recovery from an all-out 5 km run. Our analysis found that Masters runners were recovered from an all-out 5 km race on average for all TTs (48, 72 and 96 hours). Most Masters Runners (90% in our study) may be able to fully recover in 48 hours of passive rest, while 10% were able to increase their performance following 48 hours of passive rest. More than half (80%) appeared able to fully recover in just 72 hours (20% were considered positive responders), however, some will take longer than 96 hours to reach full recovery to the point that they are able to improve their performance (30% of our runners were considered positive responders during TT98). Some runners may require less time to make a full recovery, to the point that more time decreased their performance (20% of participants in our study were negative responders to TT96; 50% were non-responders)). Ultimately, the amount of rest needed by Masters Runners to fully recover from an all-out 5 km appears dependent on the individual.

When investigating 5km performance following 24 hours and 72 hours of passive rest in college age runners, Bosak et al. (5), found that 72 hours of passive rest limited decline in a 2\textsuperscript{nd} 5 km
race performance. Surprisingly, although participants in the current study were much older than those in the previous study, our findings are similar; however, Bosak et al. (5) did not evaluate performance following 96 hours of passive rest.

Finally, our aim was to evaluate the impact on 5km performance of a combination of recovery aids in Masters Runners. In general we found that the recovery aids resulted in group mean run times similar to the TT96 trial and not different from baseline. In their study, al-Nawaiseh et al. (1) examined the combined effect of antioxidant vitamins, ibuprofen, cold water submersion and whey protein on short term recovery from high intensity anaerobic cycling the recovery aids were effective in maintaining both absolute and relative mean power. That study also observed that the treatment was successful in aiding the maintenance of performance in subsequent bouts (1).

Bosak et al. (5) investigated 5 km running performance following 24 hours and 72 hours of passive recovery in college age runners and found that following 24 hours of passive recovery, 5 km running performance was significantly slower compared to the baseline performance. It was also noted that there was no significant difference between 72 hours of passive recovery and baseline. Thus, 24 hours of passive recovery alone was not sufficient for full recovery in college age runners. Those findings suggest that our combinations of recovery aids were helpful in maintaining a level of performance, 24 hours after baseline trials, while passive recovery, alone, is insufficient for maintaining performance (5).
Our data suggest that Masters Runners were fully recovered from an all-out 5 km race after both 96 hours of passive rest, and after 24 hours of passive rest plus a combination of recovery modalities. Most Masters Runners (90% of our runners did not run substantially slower) may be able to fully recover in as little as 24 hours of rest combined with these recovery modalities, or following 96 hours of passive rest. Twenty-four hours of passive recovery, even when combined with recovery modalities may not be sufficient for masters runners to see an increase in performance (only one runner in our study was a positive responder), but 96 hours of passive recovery, may be too long for a few runners and may even cause a decline in performance below BL (0% in our study were positive responders, and one was a negative responders). Ultimately, the amount of rest needed by Masters Runners to fully recover from an all-out 5 km appears dependent on the individual.
REFERENCES


APPENDIX

UNIVERSITY OF ALABAMA INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN SUBJECTS
REQUEST FOR APPROVAL OF RESEARCH INVOLVING HUMAN SUBJECTS

I. Identifying information

<table>
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<tr>
<th>Principal Investigator</th>
<th>Second Investigator</th>
<th>Third Investigator</th>
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<tbody>
<tr>
<td>Name: Kim Shaw</td>
<td>Phil Bishop, EdD</td>
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<tr>
<td>Department: Kinesiology</td>
<td>Kinesiology</td>
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<td>College: Education</td>
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<tr>
<td>University: University of Alabama</td>
<td>University of Alabama</td>
<td></td>
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<tr>
<td>Address: Box 870311, East Annex</td>
<td>Box 870312, Moore Hall</td>
<td></td>
</tr>
<tr>
<td>Telephone: 334 327 0723</td>
<td>205 348 8370</td>
<td></td>
</tr>
<tr>
<td>FAX: 205 348 0867</td>
<td>205 348 0867</td>
<td></td>
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<tr>
<td>E-mail: <a href="mailto:krshaw@crimson.ua.edu">krshaw@crimson.ua.edu</a></td>
<td><a href="mailto:pbishop@bamaed.ua.edu">pbishop@bamaed.ua.edu</a></td>
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Title of Research Project: Masters Athletes: Time to recovery after an exhaustive bout of aerobic exercise

Date Printed: 10/20/09 Funding Source: None

Type of Proposal: [ ] New [X] Revision [ ] Renewal [ ] Completed [ ] Exempt

Attach a continuing review of studies form

Please enter the original IRB # at the top of the page

UA faculty or staff member signature: [Signature]

II. NOTIFICATION OF IRB ACTION (to be completed by IRB):

Type of Review: [X] Full board [ ] Expedited

IRB Action:

[ ] Rejected Date:  

[ ] Tabled Pending Revisions Date:  

[ ] Approved Pending Revisions Date:  

[ ] Approved—this proposal complies with University and federal regulations for the protection of human participants.

Approval is effective until the following date:  

Items approved:

[ ] Research protocol: dated  

[ ] Informed consent: dated  

[ ] Recruitment materials: dated  

[ ] Other: dated

Approval signature [Signature] Date 3/1/10
THE UNIVERSITY OF ALABAMA
HUMAN RESEARCH PROTECTION PROGRAM

UNIVERSITY OF ALABAMA INSTITUTIONAL REVIEW BOARD

The University of Alabama College of Human Environmental Sciences: Department of Kinesiology

Title of Research: Masters athletes: Perception of and time to recovery following an exhaustive bout of aerobic exercise

Investigator(s): Kim Shaw, Dr. Phil Bishop, Colleen Geary and Yang Zhang

IRB Approval #: OSP #:

Sponsor:

We are asking you to be in a research study.

The name of this study is, "Masters Athletes: Perception of and time to recovery following an exhaustive bout of aerobic exercise."

This study is being done by Kim Shaw, Colleen Geary and Yang Zhang. All of these people are exercise science graduate students at U A. Dr. Phil Bishop is the faculty advisor for this study.

What is the purpose of this study—what is it trying to learn?
This study is trying to find out how much time is needed to fully recover from hard exercise. We also want to find out if an older athlete can judge how recovered they are (from previous exercise) before they exercise again.

Why this study important—what good will the results do?
The results of this study will help show us how well older athletes can tell if they are fully recovered or not before they exercise again. These findings may also help athletes change their exercise plan so that they don’t get hurt. We will also learn more about how older athletes respond to repeated exercise sessions. We will give you information about your fitness level (VO₂ max and body fat percentage). We believe that this study will provide valuable information to people close to your age who exercise.

Why have I been asked be in this study?
You are being asked to be in this study because you: appear healthy, are in the age range being studied, run regularly and run races that are 5k or more. And, your run time is in the average range for Master’s athletes.

How many other people will be in this study?
This is a small study. Only 12 (6 men and 6 women) runners aged 50–65 will be in this study.

What will I be asked to do in this study?
If you agree to be in this study, you will exercise 6 times. We will measure your 5K run time after you have rested for different amounts of time. We will also measure your 5K run time after you
have rested for 24 hours and have also taken over-the-counter supplements (thought to help people recover faster from exercise). We will give you vitamin A, C, and E, ibuprofen, and a protein drink, and ice packs for both calves. We will compare the times for your last 4 sessions with your very first one.

Before each session:
- **DRINK PLENTY OF FLUIDS AND DO NOT DRINK ALCOHOL FOR 24 HOURS BEFORE EACH SESSION.**
- Report for each session WELL-RESTED (avoid hard exercise for at least 24 hours before each session).
- 6 hours before each session, DO NOT drink any caffeine.
- 3 hours before each session, STAY AWAY FROM EATING HEAVY FOODS (fried foods or a lot of any kind of food)
- If you are sick, even slightly, please let us know BEFORE coming in.

What will I be asked to do during each session?

Health Risks
Your first session will be in our lab located in room 201 and 203 Moore Hall. You will answer three questionnaires about your current health status (forms are provided immediately after this consent form). We will use these to decide if it is safe for you to be in our study. Your information will be confidential. It is important that you answer these questions accurately and completely. If you have any questions, please ask. All questions that you may have about the study or the forms you complete will be answered to your satisfaction. We may remove you from this study without your consent, if these forms show that it may not be safe for you to participate, or any other issues come up suggesting that it would not be safe for you to continue. This session will take about 20 minutes.

Exercise sessions
All exercise sessions, except for the first maximal exertion treadmill test, will take place outside (around the University of Alabama Quad) during similar times of the day as your previous sessions. The first exercise session will be done in our lab located in room 201 and 203 Moore Hall. It will take at least 16 days (start to finish) to complete all of the running sessions. The sessions will be done on 6 separate days. You will be allowed to rest for at least 24 hours but no more than 3 days between each session. Remember that you can quit the study at any point without losing any benefits. You will be asked to complete the following 6 exercise sessions but not necessarily in the order that they are listed here.

1) **Anthropometric measurements**: Just before the start of your first exercise session we will measure things that describe you (age, height, weight, and percent body fat). We will estimate percent body fat by measuring skin fold thickness at your chest, stomach, and thigh for males; arm, hip and thigh for females. In this process we pinch your skin and use a small device to measure the thickness of the pinched skin. It usually does not hurt.

**Maximal exertion** (the most intense exercise you can do) **treadmill test**: During this session you will walk and run on a treadmill for 15-20 minutes. During exercise, we will make it harder by increasing the speed and grade of the treadmill every 3 minutes. The first part of the test will be very easy but the test will get slightly harder every 3 minutes and it will get very hard after several minutes. When you feel you can no longer keep running at the required pace, the test will be stopped. We will be monitoring you during a low intensity cool-down. We will also stop the test if we feel that it is not safe for you to keep going. During this treadmill test, we will
require you to wear a breathing mask. It will cover your nose and mouth but you will be able breathe room air with no problem. This session takes about 30 minutes to complete. We will closely supervise you. Our personnel are trained in CPR and we will have an automatic external defibrillator.

B) Baseline Session: We require you to perform a 1.5 mile warm-up followed by a 5K maximal-effort run with simulated race day conditions (which will be electronically timed) and a 1.5 mile cool-down. We will give you frequent verbal encouragement. You will run against participants with similar ability. This session will last about 60 minutes.

C) Recovery Sessions: These sessions will be the same as the baseline session. You will always be allowed to drink water when you want to. Each session will last about 70 minutes. We will ask you to repeat the session following a period of 24, 48, and 72 hours of rest and after the application of a combination of techniques thought to help people recover faster after exercise. The combination of recovery techniques includes: over-the-counter supplements: vitamin A, C, and E, ibuprofen, a protein drink, and ice packs to both calves immediately after the cool-down followed by 24 hours of passive recovery. You should NOT do anything special on your own to help or hurt your recovery.

During all sessions you will be required to wear a heart-rate monitor around your chest. The monitor looks like a small belt. It does not hurt nor stick to your skin.

YOU MAY STOP ANY SESSION AT ANY TIME YOU WANT FOR ANY REASON WITHOUT PENALTY!

How much time will I spend being in this study?
You will spend about 8 hours being in this study over the next 16 days. The sessions take about 20 minute session today, and about 7.5 hours total for the 6 sessions when you will run.

Will being in this study cost me anything?
There is no cost for being in this study other than the time and energy you spend while being in the sessions.

What are the benefits of being in this study?
Information from this study will help us evaluate a new tool that can be used to determine how much an individual has recovered before they exercise again. This tool could also help individuals to change their training program so that they don’t get hurt or overtrain. We will also learn more about how older athletes respond to repeated exercise sessions. We will give you information about your fitness level (VO2 max and body fat). We believe that this study will provide valuable information to runners similar to your age.

What are the risks (dangers or harms) to me if I am in this study?
Potential risks to your health and well-being during this study include:
1. Cardiovascular injury (heart attack, stroke, and death – risk is estimated at <0.01%)  
2. Tiredness (100% likely during maximal exertion) which may induce lightheadedness, dizziness, nausea which are common. Vomiting, muscle cramping, or temporary loss of consciousness which are uncommon  
3. All other possible risks associated with intense exercise (e.g., muscle soreness, or lethargy).
In the event of an injury, we will only provide first aid for you. You will be responsible for any additional medical costs.

**How will my privacy be protected?**
We will not tell anyone you are in this study. You do not have to answer any questions or give us any information that you do not want to.

**How will my confidentiality be protected?**
We will protect your information by giving you and each person in this study an i.d. number. Your names will not appear on any study document besides this consent form. There is no way to link consent forms and names with data. We will keep all records in a locked filing cabinet in the Department of Kinesiology Human Performance Lab (201,202 Moore Hall). No one will have access to it except the investigators (Including myself, Kim Shaw, my faculty advisor, Dr. Phil Bishop, and co-investigators, Colleen Geary and Yang Zhang). We may publish scientific articles on this study, but we will not use any names. No one will be able to tell who you are.

**Do I have to be in this study?**
No. If you decide to be in this study it should be because you really want to volunteer. You can decide not to be in the study. You can also start the study and decide to stop at any time. If you refuse or if you start the study and then stop it, you will not lose any benefits or rights you would normally have.

**If we don’t want to be in the study, are there other choices?**
If you do not want to be in this study, there is no other choice. We will thank you for your time and you will be free to leave.

**What if new information is learned during the study that might affect my well-being or decision to continue in the study?**
If new information about recovery time and repeated bouts of exhaustive exercise in athletes aged 50-65 becomes available that affects this study, we will tell you about it or we will apply it to our research on the subject. If there is any indication that exercises, techniques or supplements are harmful in this study, we will stop the study or remove the danger immediately.

You can tell us at any time whether you want to continue in the study or not.

**What if we have questions, suggestions, concerns, or complaints?**
If you have questions about the study now, please ask them. If you have questions or concerns later, you can contact Kim Shaw, UA Box 870311, University of Alabama, Tuscaloosa, AL 35487-0312, (334 327 0723).

You may be reach Dr. Phil Bishop by campus mail at UA Box 870312, University of Alabama, Tuscaloosa, AL 35487-0312, by phone at (205 348 8370), by email at pbishop@bamaed.ua.edu, or in person at his office, 204B Moore Hall.

If you have any questions about your rights as a research participant you may contact Ms. Tanta Myles, The University of Alabama Research Compliance Officer, at 205-348-8461 and toll free 1-877-820-3066.
What else do we need to know?

- You do not give up any of your legal rights by signing this consent form. We will give you a copy of this consent form.
- Please save it in case you want to review it later or you decide to contact the investigator or the university about the study.
- The University of Alabama Institutional Review Board (IRB) is the committee that protects the rights of people in research studies. The IRB may review study records from time to time to be sure that people in research studies are being treated fairly and the study is being carried out as planned.
- This study is not supported by any source of funding. No one involved in this study (participant or investigator) will be compensated (monetarily or otherwise) for time spent during experimental sessions, data collection or data analysis.

I have read this consent form and freely and voluntarily agree to participate in the study described above. I understand that I can terminate participation at any time without penalty of prejudice. I have had a chance to ask questions. My questions have been answered. I fully understand what will be asked of me and I have decided to participate in this study.

_________________________ Date__________

Signature of Research Participant

_________________________ Date__________

Signature of Investigator

Page 5 of 5

Prospect Initials__________

Note: This Informed Consent is written on an 8th grade reading level