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This report overviews the work that was done in year 2 of our investigation. We completed all of the upper and total body resistance training (6 months) groups (n=17 to 21 per group) and are now examining the longitudinal data. In year 3 will work to finish the field training and endurance training groups along with completion of the normative men group. We have completed a number of acute cross-sectional studies and have made the following observations: 1. Different from prior studies in the literature with small n sizes, women can see a transient increase in testosterone in response to an acute resistance training workout, 2. A relationship between free testosterone and regional fat distribution exists in healthy women too. 3. Insulin-like growth factor response to exercise in women is related to the pre-exercise values and not related to immunoreactive growth hormone responses; 4. Post-exercise cortisol concentrations explain the immuno-suppression observed after exercise, 5. To predict abilities in repetitive lifting tasks the best predictors were 1 RM box lift and the 2 mile run time; 6. Prediction of strength from cross-sectional area of muscles can be misleading due to a high neural component not factored into many equations; 7. The relative gender difference in occupational lifting performance which requires both strength and endurance is less than in pure strength only tasks.

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William J. Kraemer Oct 19, 1997

PI - Signature Date

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INTRODUCTION

Project Time Line. This annual report covers the work that has been accomplished in the second year of our three year investigation. Due to the need for appropriate "n" sizes in each of the experimental groups, this project requires the full three years to complete all of the data collection for the six groups of women. Additionally, over this three year period we will be collecting strength and power performance data in a control group of men for gender-based comparisons. Thus, any final analyses related to the longitudinal training questions posed in this investigation will not be available until the final report of the project. Where appropriate, we will utilize cross-sectional data analyses to generate new information and publications related to our project. We have included the abstracts from our presentations of our cross-sectional data. We completed the four experimental groups involved with different resistance training/endurance training protocols in year two. We used this information gained on program design in the first two years to design the field training protocol for the final year. We are currently working on completion of both the endurance training and field training experimental groups. The strength and power control testing of men continues to be accomplished in an ongoing fashion until we complete the needed number of subjects (n=100).

Theoretical Background of the Study. With the changing roles of women in the United States Army, the physical demands will only increase as we move into the 21st century. The primary physical demands of the majority of military occupational specialties (MOS) are related to muscular strength and power capabilities where women, on average, produce in a range of 35-86% of men [1-3]. Comparatively speaking, women average only 56% of the upper body strength and power of men; they do somewhat better when one compares lower extremity performance (71%). The primary problem is that in order for the average woman to gain parity with the average man, she must dramatically increase her strength (i.e., up to 65% increases required depending upon muscles involved). Others have tried to meet this goal but have fallen short, primarily because their heavy resistance training programs have been relatively unsophisticated and have not been carried out long enough.[4-7] Our investigation utilizes more advanced training programs of longer duration for women which appears to be required to achieve higher levels of adaptation in muscle strength and power when compared with average men.[1,3] To date, limited information is available on more advanced training programs in women. Except for

the anecdotal knowledge that certain women athletes develop superior muscle strength, power, and size when compared to average men, our knowledge remains incomplete. Finally, we feel that in order to fully understand potential physiological limitations, mechanisms of adaptation, and the impact that advanced resistance training programs may have on the health status of women, a strong underlying biological component was necessary for the investigation.

Fully $^{1}/_{3}$ of the non-combat operations that women could theoretically do are those which require the soldier to lift, carry, push, or pull loads in excess of 40 kg.[1,8] However, the most recent information has shown that only 30-40% of women could actually perform these types of tasks if they were required to do so. Furthermore, there are good reasons to believe that this situation can be improved by new strategies that involve state-of-the-art resistance training regimens.[9]

Contribution of Upper Body Strength to Functional Abilities. The contribution of upper body strength to whole body performance has never been fully evaluated. In fact, the only limited data available are those in men in which the contribution of upper body strength training to performance or tasks relevant to the military was defined. For example, in 1987 the Principal Investigator studied the effects of upper body strength training in male soldiers on load bearing and performance in the Army Physical Fitness Test (APFT).[10] Upper body strength training, together with aerobic endurance training, was done for three months. In that study, the experimental design included the following four groups: 1) total body strength and endurance training; 2) upper body strength and endurance training; 3) endurance training only; and 4) strength training only. Only those in the upper body and total body strength training groups improved in both APFT measures and two mile load (backpack load of 44.7 kg) bearing tasks of a similar magnitude. These data showed that aerobic endurance, upper body strength, and upper body power are the primary contributors to APFT and load bearing performance. Since women are at an even greater disadvantage in terms of upper body strength and power, we hypothesize that the contribution of upper body strength and power to physical fitness and load bearing are the key targets for heavy resistance training.

All military-relevant tasks involve strength and power contributions from the upper body musculature. A lower absolute magnitude of upper body muscle tissue is thought to be the primary contributor to reduced strength and power capabilities of

women.[3,2] Thus, enhancing the quantity and quality of upper body muscle tissue may well contribute to the majority of the enhanced physical performance capabilities in women. To date, no studies have directly examined the contribution of upper body resistance training in women. Thus, our investigation will study the role of improving upper body strength and power and determine its impact on performance.

Strategies for Enhancing Strength, Power, and Muscle Size in Women. Resistance training programs can be specifically designed to enhance both muscle tissue mass and/or neuromuscular function.[3,9] The neural component enhances strength and power capabilities via neural mechanisms while placing little or minimal demand for the hypertrophy of activated muscles.[11,12] Conversely, the muscle tissue component results primarily in the enhancement of strength and power via increase in muscle size due to protein accretion and increased hypertrophy.[13,14] These are the primary physiological mechanisms by which resistance training is thought to produce increases in strength, power, and performance.

Training programs which focus on the neural component utilize higher intensities (i.e., percentages) of the 1 repetition maximum (1 RM) in that training.[15] They are characterized by longer rest periods between the sets and exercises as well as lower volumes of work. Conversely, programs which focus on the muscle tissue component utilize a lower range of percentages of the 1 RM, shorter rest periods between sets and exercises, and higher volumes of work[15]. Thus, strength and power performance is mediated by two different adaptational routes; those routes can be manipulated and studied independently for their effectiveness.

For many years it had been thought that women gained strength primarily through neural mechanisms because only small changes in muscle size were observed.[4,3] To be fair, it must be pointed out that all of the studies reaching this conclusion did not use an optimal muscle hypertrophy training program; nor did they examine training responses in a period of time that would be long enough to reveal adaptations in the muscle tissue component. A recent study published by Staron *et al.* (1994),[16] demonstrated that in the first 8 weeks of training, no changes in muscle fiber size take place in men or women. However, alterations in the types of myosin heavy chain protein and muscle enzymes do. Thus, while neural adaptation may appear to predominate in the early phases of training prior to observing muscle hypertrophy, this could reflect the need for alterations in the muscle proteins prior to

the time that protein accretion starts to occur to any significant extent.[15] Clearly, longer periods of training time will be needed to fully evaluate the potential for other physiological strategies to contribute to the goal of enhanced physical performance. Since muscle tissue mass is the ultimate limiting factor in muscle strength, a better understanding of the strategies that enhance it are of great value. Our approach evaluates the interaction between neural and hypertrophy components and seeks to optimize them. Our research strategy enhances the chances to determine the best way to meet the overall physical training goal efficiently and effectively.

Contributing Hormonal Factors. Short-term "normal" strength training in women usually does not lead to changes in serum levels of endogenous hormones beyond the normal physiological range.[18] However, the balance between anabolic (e.g., testosterone, growth hormone, insulin-like growth factors) and catabolic (e.g., cortisol) hormones is likely to become increasingly important especially during prolonged resistance training. Not all types of workouts produce the same alterations in anabolic and catabolic hormonal responses.[19-21] In fact, hormonal balances and responses to heavy resistance training follow a distinctly different pattern for a "strength/power" workout compared to a "muscle tissue/hypertrophy" workout.[20] Because hormones are the driving force by which cells make changes to adapt to their environmental needs, and because changes at the cellular level ultimately translate into changes in whole body function, hormone measurements in our various test subject groups are important to the underlying understanding of the mechanisms of adaptation. The fact that the anabolic/catabolic hormone ratio changes between "strength/power" vs. "muscle tissue/hypertrophy" [22,23,11] lends additional validity to our experimental design.

Growth hormone is poorly named because it is a metabolic hormone which controls multiple organ systems (muscular, skeletal, immune, and liver) throughout life in addition to promoting bone growth during adolescence. It is therefore not surprising that there is 800x more GH in the pituitary than any other hormone! There is compelling evidence to show that multiple forms of hGH molecules are found in both the human pituitary gland and in human plasma.[25-28] The evidence that some of these forms have different bioactivity (b) to immunoactivity (i) ratios is equally compelling. For example, the b/i activity ratios of human plasma is 200![26] This is an astonishing number because it shows that the technique conventionally used to measure blood levels of hGH (i.e., radioimmunoassay) fails to detect forms of the

molecule which are biologically relevant, i.e., that promote bone and muscle growth. There are good reasons to believe that the kind and amount of GH released from cells of the pituitary gland depends upon disease state and general state of fitness.

It is our belief that anabolic hormones are the key, primary physiological regulators that ultimately control and limit the body strength of the human female. Our experimental design allows us to monitor what we believe to be the most important anabolic hormones (GH, IGF-1, and testosterone) in such a way that we will have a much better picture of the optimal chemical environment around muscle tissue that is responsible for achieving the desired result: increased muscle strength/power of the human female.

Heavy Resistance Training In Relation To Women's Health and Immune Function. The physical demands of a soldier in the Army are directly analogous to that of an athlete where advanced physical preparation or training is required for meeting the demands of the job.[1,29] When additional physical stress is added to a lifestyle, additional physiological stress is usually observed. That stress can seriously compromise toleration of rigorous training programs of the type we are studying. Herein we face a potential dilemma; viz. how do we optimize women's training programs in a situation where the high level of physical training could negatively affect the health status of the individual? Obviously we need a simple, straightforward way to monitor health status; we propose to do so via well-known techniques that collectively are classified as immunology.

The immune system not only protects from acute insult delivered by infections and disease-causing agents but it also maintains a constant state of health by response to and modulation of many internal signals. In this specific regard, the immune system probably interacts with every other organ system in the body. The strongest evidence to date shows that cells of the nervous, endocrine, and immune system communicate via soluble mediators, hormones, interleukins, and their cytokines. Evidence that both estrogen and androgens can directly affect immune organs and cells is compelling.[30] At the whole body level, the immune response (cell-mediated and humoral) of females is generally greater than that of men. Women are usually less susceptible to challenge with infectious and toxic agents. In addition, certain autoimmune diseases are much more likely to occur in males. The need for the women to adapt immunologically to pregnancy is perhaps the most clear-cut

example of gender differences in immune responsiveness. Furthermore, the immune system is affected by stress hormones. One such stressor is exercise; it dramatically increases amounts of immune cell interactive hormones such as cortisol, growth hormone, prolactin, and catecholamines.[18,31,32]

Initial evidence shows that women do not tolerate high intensity power training as well as men. This phenomenon is reflected by a plateau (i.e., leveling off) in strength gains observed at about 2 to 4 months.[23,33] Plateauing could represent (1) a shift in the physiological strategies that the body uses as it changes from primarily neural adaptations to primarily muscle hypertrophy adaptations, or (2) reflect an overtraining syndrome due to the associated stress at the cellular level related to muscle cell remodeling. The latter stress is associated with increased protein accretion and turnover that is needed for muscle hypertrophy and involves "cleaning up" the cell from the exercise-induced damage associated with the remodeling process rather than fighting disease.

Viewed together, these results not only underscore the complexity of the problem, but also validate our thesis that design of the resistance training program is not simple, but can be manipulated in a scientifically predictable way to achieve a desired result. The sheer physical stress associated with tissue remodeling of the neuromuscular unit can lead to stress on the immune system, thus hampering training progress due to illness.[34] Thus, understanding the health impacts, physiological adaptations, and performance changes of such advanced training is a vital issue related to women's health.

Statement of Work. The statement of work for this investigation is provided in this annual report for year two in order to overview our primary work tasks related to this investigation. We have addressed all of the different work statements over the first and second years of the project. At the present time we have completed the four groups of resistance training women and have added men to our normative men group as well.

STATEMENT OF WORK

1. Pilot test all experimental variables and equipment
2. Recruit, gain informed consent, medically screen, familiarize, and pre-test women and men
3. Match, balance and randomize women into subject groups
4. Perform training familiarization
5. Initiate supervised physical training programs
6 Perform data collection at 0 (T-1),3 (T-2) and 6 (T-3) months for training groups
7. Perform biochemical and immunological assays
8. Perform magnetic resonance image scans of upper and lower limb musculature
9. Perform electromyographical and strength test evaluations
10. Coordinate with the United States Army Research Institute's Military Performance Division military relevant physical performance task tests at Penn State.
11. Develop computer data base management scheme and perform data entry and analyses over the course of the experimental period.
12. Utilize phase one weight room data to develop optimal strategies for program design of "field training" resistance program for year three.
13. Analyze data set and provide appropriate reports, physical training recommendations, and scientific publications on physical training of women.

METHODS

We have completed four experimental groups involved with different resistance training/endurance training protocols. We used the information gained on program design in the first two years to design the field training protocol for the final year. We will then in the final year complete both the endurance training and field training experimental groups. The strength and power control testing of men are being accomplished in an ongoing fashion until we complete the needed number of subjects.

Subject Characteristics We have recruited in our first phase healthy young men and women in the age range of 18-32 years. The matching process involves a six women group with open spots for women in the field training and endurance training groups in year three. Thus, our goal has been to match and randomize and make sure that their are no significant differences between the groups for such variables as

age, body mass, % body fat, androgen levels, activity background, menstrual cycle status, strength, and power prior to the start of the study. The project has been approved by our Institutional Review Board for Use of Human Subjects and all subjects after a briefing on the investigation are asked to give their informed written consent to participate. They are then medically screened (including EKG and pregnancy testing) by our physician who is a part of the research team.

Experimental Design. To test the various hypotheses set forth in this investigation, we will utilize 6 groups of women (4 experimental weight room training groups, an endurance training control group, and a field training group. We also will collect strength/power performance data on a group of men for gender comparisons. The training programs will consist of 6 months of training (3 days/week) with testing performed at 0, 3, and 6 month intervals in order to be able to accomplish all of the needed testing. Familiarization with training and testing protocols will limit gains which can be attributed purely to learning effects!

EXPERIMENTAL GROUPS

Women

(Completed Years 1 and 2)

Resistance Training/Endurance Training Groups (Years 1 and 2) N Size Completed (Bold)

1. Upper Body Strength/Power (targeted n size of 15-20) **(N =21)**
2. Upper Body Hypertrophy/Strength Endurance (targeted n size of 15-20)**(N =18)**
3. Total Body Strength/Power (targeted n size of 15-20)**(N =17)**
4. Total Body Hypertrophy/Strength Endurance (targeted n size of 15-20)**(N =19)**

---------- **Groups ongoing in year 3 below**----------

(Year 3)

5. Endurance Training Control Group (targeted n size of 15-20)
6. Field Training Group (targeted n size of 15-20)

Men

(Years 1 to 3)

Normative Male Comparison group (targeted n size of 100) **(86 tested so far)**

Experimental Heavy Resistance Training Groups. Subjects in these groups will all participate in a supervised endurance training program identical to that of the

endurance training control group. In addition, each subject will perform the supervised resistance training program outlined for each program.[3,35] Periodized heavy resistance training programs are fully supervised and individualized as to progression in intensity, number of sets, rest between sets, and volume of exercise performed.[3,9,39] See Appendix 1 for example periodized progression cycles for each resistance training protocol. Variation will be provided over week of the training program within the range of program parameters where strength power groups lift weights only 8 RM or lower with longer rest periods and hypertrophy-strength endurance groups lift weights 8 RM and higher and use shorter rest periods. The exercises are similar, except for the obvious lack of lower body strength exercises in the upper body groups. The dramatic contrasts in the programs will allow us to see how much differentiation exists with resistance training program design in women. The 6 month duration of this training program is vital in the attempt to maximally affect the magnitude of training related adaptations and to determine if any plateaus exist for these training programs. Free weights and commonly available weight training machines will are used to perform the exercises.

Endurance Training Control Group. Due to the fact that the U.S. Army promotes aerobic endurance training as a part of the soldier's total fitness program, we feel that it is vital that we utilize physically active women in this study.[36] Thus, to be consistent with a soldier's typical fitness program, all subjects will carry out a supervised endurance training program of three days a week for 30-45 minutes. It has been shown that endurance training of this magnitude does not interfere with strength or power development in women.[37]

The Field Training Group. This group will initiate its training program after the completion of the "weight room" study phase of this investigation. We must first utilize the most sophisticated training protocols and equipment to see if the gender gap in strength and power can be significantly minimized. Once we know the characteristics of the most effective resistance training programs in the weight room, we will determine how many of these adaptational changes can be achieved with various exercises in the field, not utilizing formal weight room equipment. Only partner exercises, common equipment resistance, manual resistance exercises, isometrics, and various types of plyometric drills will be utilized. Comparison of the field training and weight room results will indicate the potential utility of such physical training programs in the Army. Data from U.S. Army basic training demonstrate that many

women soldiers gain strength with current physical training programs, but these gains are not enough to markedly impact MOS load demands for strength and power (Sharp, M. *et al.* USARIEM unpublished data).

Normative Male Comparison Group. In order to compare how the gains made by women in the different training programs directly affect performance relative to men, a normative group of men will be used in this investigation to provide data on muscle size (MRI), strength, power, and militarily relevant task performance tests. About 100 healthy men will be matched for age and activity background with the women in the training study. The goal will be to have a group of men who are representative of the average height and weight range of soldiers in the U.S. Army based upon data from Fitzgerald *et al.* (1986).[38]

EXPERIMENTAL TESTS

The following section of the report briefly overviews the experiemtal tests used in this investigation.

Strength/Power Tests. The Plyometric Power System (PPS)[40,41] was developed to overcome the injury risks and inefficiencies of other methods for the more sophisticated assessment of human muscular strength and power. To provide resistance for testing and training, the PPS uses a barbell to simulate a mass used in occupational and sporting activities. It is much more similar to normal human activity than are isokinetic devices which require constant speed movement. The PPS is interfaced to a computer making it a very accurate measurement tool which provides detailed information concerning the kinematics and kinetics of the performance. The variables recorded include displacement, velocity, acceleration, force, and power output with respect to time as well as indices of explosive power performance such as rate of force development and time to peak force. The PPS allows the individual to be tested and trained under conditions of maximal power and strength output in an environment of total safety. Limiting catches prevent injury through falling or loss of control of the loaded bar and a specially designed electromagnetic braking mechanism can control the eccentric loading on the subject from zero to full bar weight. Vertical ground reaction force will be measured by means of an AMTI force platform, the amplified signals of which will be passed to a DT21-EZ analog to digital card (Data Translation) in a 80486DX computer running Windows 3.11. The digitized

data will be stored on computer disk for later analysis. The force measurement system are calibrated prior to all testing sessions.

Three movements are to be tested: 1) The High Pull will involve the subject lifting the weight from the floor level to a position at chin level; 2) The Squat will be performed from a knee angle of 90 degrees flexion to a standing position with the bar held in the high back squat position; and 3) The Bench Press will involve pushing the bar vertically upwards from the chest position. The strength and power capacity of the subject will be assessed during the entire concentric exercise phase. During the first testing session, the subject's one repetition maximum (1 RM) load for each of the test movements will be determined.[42,43]

During subsequent test sessions the PPS will be loaded with 30%, 60% and 90% of the subject's previously determined 1 RM for the squat jump. Each subject will complete a single, maximal explosive effort with the required load. Three trials will be completed for each test movement. The order of the test movements and loads will be randomized among subjects to reduce the possible confounding effects of fatigue or boredom. A 1-2 minute rest period between attempts will be utilized. During each trial the PPS will record the displacement-time data, are being collected and stored for later analysis.

Maximal voluntary unilateral isometric peak force, force-time, and relaxation time parameters of the knee extensor muscles will be measured separately for the left and right leg. The subject is in a sitting position on a special chair (a modified version from Cybex) so that the knee angle will be 90°. The force output will be recorded using resistive force transducers in series with a chain securing the subject's leg. The subjects are instructed to respond to a command by exerting their maximal force as rapidly as possible during a time period of 2.5-5.0 seconds. They will also be instructed to relax the force as fast as possible after the required contraction time and having reached their maximal force. Three to four maximal contractions will be recorded separately for the left and right leg until maximal peak force (N) is obtained. The force-time analysis will include the calculation of average force (N) produced during each consecutive time period of 100ms in duration from the start of the contraction as well as the maximal rate of rise of force production ($N \times s^{-1}$). The relaxation time curve will be analyzed in the relaxation phase of the contraction to record the time (ms) needed to relax the force. Only the actual relaxation time is

analyzed without the reaction time to signal given for the start of the relaxation. In order to evaluate muscle activation relative to determining the changes in the neural component, electromyography is being utilized for isometric knee extensor tests.[11,23,33] During all trials, each subject will have silver/silver chloride surface electrodes attached over the belly of the prime mover muscles. Two active electrodes separated by 2 cm will be attached to the belly of each muscle and a third ground electrode attached to the lateral malleolus. The active electrodes will be aligned parallel with the fibers of the muscle under investigation. Before electrode application, each site will be shaved, cleansed with alcohol, gently abraded and a small amount of conductive gel applied to each electrode. The impedance between each electrode pair will be measured to ensure resistance is below 5000 Ohms. The signals will be amplified using a Noraxon EMG amplifier and the amplified myoelectric signals will be collected using a 80486DX computer running Windows 3.11 and a DT21-EZ analog digital card (Data Translation). The digitized data will be stored on a computer disk for later analysis.

EMG data will be quantified in two ways. 1) The average EMG will be calculated by full wave rectification followed by integration with respect to the time over the concentric phase, then divided by the time of the concentric phase. 2) Peak EMG will be calculated by integrating the rectified EMG over consecutive 50 ms time periods and determining the highest activity level.

Resting and Exercise-Induced Blood Collections for Hormone and Immune System Analyses. Before and after the relative endurance strength test (6 x 10 RM), resting and post-exercise blood samples will be collected into appropriate serum, plasma, or whole blood collection tubes and then processed, centrifuged, and stored where appropriate at -85^{o} C, and analyzed according to previously described methods for serum hormone concentrations for serum hormones[19,20,21,44,45] [testosterone, free testosterone, sex-hormone-binding globulin, growth hormone(s)(bioactive [pre-post-training] and immunoreactive), cortisol, and insulin-like growth factor I]. In addition, hematocrit, hemoglobin, plasma volume shifts, and blood lactate, will be determined via standard methods we have previously used.[19] (see Appendix for assays set up on bioactive Growth hormone fractions)

In order to adequately monitor the immune system [pre-mid-post-training], white blood cell differential counts, mitogen responsiveness *in vitro*, and cytokine

production will be measured. In addition, lymphocyte phenotyping will be carried out. Many of the immune stress measures will be identical to the Army's study of the stress associated with Ranger training and will allow comparison of stressors.[29]

1. Complete blood counts and white blood cell differential counts will be obtained on resting samples.
2. *Mitogen responsiveness in vitro.* Both T and B lymphocytes respond to appropriate mitogens in culture by activation leading to DNA synthesis. Standard protocols will be used for isolation of human mononuclear cells from blood using leukoprep separation techniques.[46] White blood cells will be resuspended in culture medium, RPMI-l640 plus l0% heat inactivated human AB serum and assayed in a 96 well microculture plate with T cell mitogens phytohemagglutinin-M (PHA), Concanavalin A (Con A), or tetanus toxoid (TT). The former are polyclonal, non-antigen specific stimulators; the latter will evoke a secondary antigen response. Pokeweed mitogen (PWM) will be used to stimulate T and B lymphocytes; lipopolysaccharide (LPS) will be used to stimulate B lymphocytes. Cultures will be pulsed with ^{3}H-thymidine following standard protocols. Preliminary experiments will be done to optimize concentrations and pulse times.
3. *Cytokine (Interleukin) production.* Activated lymphocytes produce bioactive peptides, collectively called cytokines or interleukins (IL). IL-2 and IL-4 produced by activated T lymphocytes regulate other T and B cells. IL-2 is made by the T_H1 subset; IL-4 by the T_H2 cells. IL-6, a major cytokine in inflammation, acts both on endocrine (pituitary) and immune cells. These interleukins will be measured in the culture medium of unstimulated and mitogen and antigen stimulated blood cells by commercially available ELISA kits.
4. *Surface differentiation antigens.* Subpopulations and maturational stages of lymphocytes can be distinguished by monoclonal antibodies to cell surface antigens. Exercise has been reported to change the composition of the blood in respect to these subpopulations of cells, possibly by altered cell trafficking caused by changes in blood circulation. We will use a panel of monoclonal antibodies to quantify subpopulations of cells and to examine expression of certain adhesion molecules (selectins and integrins) important in cell trafficking.

Analysis will be performed on unseparated cells in whole peripheral blood.[46] Briefly, l00 ml whole heparinized blood will be incubated with each antibody followed by a fluorescent second antibody. Red blood cells will be lysed, the white blood cells fixed with l% parafarmoldehyde and the samples analyzed by flow cytometry which will be used to quantify stained cells and determine percentage composition of the blood.

Magnetic Resonance Imaging (MRI) MR images will be collected at 0, 3, 6 months using our clinical MRI 0.5-Tesla super conduction magnet (Picker International Inc., Highland Heights, OH) for each of the resistance training groups. Analysis of the cross-sectional area (CSA) muscle sizes of both thighs and upper arms will be determined from the MRI scans using a gradient echo technique which allows the greatest delineation and distinction between muscles and has been shown to be more sensitive than CT scans for determining muscle size changes. Appropriate internal controls and phantom evaluations will be obtained. Seventeen contiguous transaxial images 1 cm thick will be obtained between standard anatomical landmarks. All MR images will be ported to a Macintosh computer for calculation of muscle CSA using a modified version of the Image software package available at no cost from the National Institutes of Health, Research Services Branch.

Militarily Relevant Task Performances. The following militarily relevant task performance tests will be administered at 0 and 6 months of the investigation at Penn State by the USARIEM: Occupational Physiology Division.

Backpack Load Carriage. Subjects will transport a 75 lb. load using standard external frame Army backpacks (ALICE Pack) as rapidly as possible a distance of two-miles over a paved, flat surface (road or track). Time will be recorded as the measure of performance. The 75 lbs. approximates the maximal acceptable load for approach march conditions, e.g. prolonged road march operations where contact with the enemy is unlikely [(47)]. The ability to carry backpack loads over long distances is a uniquely relevant military task which is required of all soldiers.

Maximal Lifting Capacity. The maximal amount of weight that can be lifted in a box with side handles from the floor to 132 cm (height of the bed of a 2 1/2 ton truck) will be determined. Following instructions on proper lifting technique and appropriate warm-up, subjects will lift the incrementally weighted boxes beginning with a light weigh until the subject can not safely complete a lift. After a failed attempt, weight will

be removed to yield a load between the failed load and the highest successful lift. The 1 RM box lift will thus be measured as to the nearest 1.0 kg.[48].

Repetitive Lifting Capacity. Repetitive lifting capacity will be measured using a 45 lb. box and 2 platforms placed 8 feet apart at the height of the back of an Army truck (height 76 cm). Subjects will lift the weighted box from the floor, turn to their right or left, and place the box on a other table and walk over to the other platform to place another box on it.. Technicians return the boxes to the floor. Subjects will complete as many lifts as possible within 10 min. Repetitive lifting is another very common physical task found in a number of military occupational specialties [49].

Army Physical Fitness Test. Each subject will perform the Army's physical fitness test which consists of the maximal number of push-ups that can be performed in 2 minutes, the maximum number of sit-ups that can be performed in 2 minutes and time for a 2 mile run on a measured track [36]. A comparison will be made between the results of this standard Army test and other physical tests administered in this study.

Health and Dietary Monitoring. Each subject's health status and nutritional intake are of great concern to us in order for each women to continue with their training programs and meet the caloric expenditures of advanced training. We will monitor health status by having our physicians available for appointments and will collect clinical data concerning illness. Appropriate health care and subject monitoring will be used to avoid any extended absences from training. Computer analyses of intake diaries and counseling by our nutritional staff of registered dietitians will occur prior to and throughout the study to make sure that the dietary intakes can support the nutritional demands and caloric expenditure of training.

Time/Work Hours. The following information is provided in order for the reader to gain a understanding of the amount of time and number of personnel involved with a physical training study of this magnitude.

Logged Total Hours For Investigation Over the First Year

1. Total Training Hours (research assistant trainers and testing assistants):
   1550 hrs
   - combined trainers and testing assistants...
     72 personnel

2. Total Supervision and Testing Hours
   plus Hours for Training Supervisors (organizational meetings and supervision):

   6023 hrs
   - **8** training supervisors
   - **5** overall supervisors
     (includes areas of team leader, training, nutrition, assistant supervising)
     total of **13** personnel

3. Total Hours for Blood work (collection, processing, and assay analyses):
   6500 hrs
   - **7** personnel for complete immune analyses
     6 personnel for RIA, Bio-active analyses, clinical chemistries

4. Total Hours Subjects for Supervised Training and Testing:
   14000 hrs 4 groups completed
   -

5. Performance Testing in Men
   602 hours to test 51 men
   8 personnel

Grand Total:

≈ 28675 **contact hours.**
≈ 106 total personnel plus investigators

Statistical Analyses. We have developed a computer data base for the investigation. We will use common descriptive statistics to describe the data sets. In addition, a wide range of multivariate statistical analyses will be used to determine group differences, main effects, interactions, and relationships between variables. When appropriate, non-parametric analyses will also be used. Significance in this investigation has been set at $p \leq 0.05$.

RESULTS

In this second annual report we have completed the results of cross-sectional studies and present the abstracts from these meetings. In addition we are currently working on individual manuscripts on cross-sectional data along with papers on our resistance training groups after laboratory and statistical analyses are completed in the laboratory. We will try to give the reader of this document some preliminary data which may provide some insights and examples of our data set and collection and provide some preliminary data where possible.

CONCLUSIONS

At this point in the study no conclusions can be drawn as to the outcome of the longitudinal aspects of the study. The cross-sectional study abstracts give the indication of the findings thus far in these studies.

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APPENDIX 1

EAXMPLE WORKOUT PERIODIZATION SHEETS FOR EACH RESISTANCE TRAINING GROUP

NAME: _____

GROUP: Upper Hyper
TRAINER: _____

DAY 1

Rest between Sets			Date Time In: Out:	Date Time In: Out:	Date Time In: Out:
60 sec	Bench Press	4 x 8 reps			
60 sec	Seated Row	4 x 8 reps			
60 sec	DB Press	3 x 8 reps			
60 sec	Lat Pull Down	3 x 8 reps			
30 sec	EZ Curl	3 x 8 reps			
30 sec	Tricep Pushdown	3 x 8 reps			
30 sec	Rotational Crunch	3 x 30 reps			
30 sec	Back Extension	3 x 8 reps			
X	Cardiovascular	25 min			

DAY 2

Rest between Sets			Date Time In: Out:	Date Time In: Out:	Date Time In: Out:
60 sec	DB Incline Press	3 x 8 reps			
60 sec	Front Pull Down	3 x 8 reps			
60 sec	Upright Row	3 x 8 reps			
60 sec	DB Row	3 x 8 reps			
30 sec	DB Curl	3 x 8 reps			
30 sec	DB Tricep	3 x 8 reps			
60 sec	Sit-up	3 x 30 reps			
X	Cardiovascular	25 min			

DAY 3

Rest between Sets			Date Time In: Out:	Date Time In: Out:	Date Time In: Out:
60 sec	Bench Press	4 x 8 reps			
60 sec	Seated Row	4 x 8 reps			
60 sec	DB Press	3 x 8 reps			
60 sec	Lat Pull Down	3 x 8 reps			
30 sec	EZ Curl	3 x 8 reps			
30 sec	Tricep Pushdown	3 x 8 reps			
30 sec	Rotational Crunch	3 x 30 reps			
30 sec	Back Extension	3 x 8 reps			
X	Cardiovascular	25 min			

NAME: _____

GROUP: Upper Hyper
TRAINER: _____

DAY 1

Rest between Sets			Date	Date	Date
90 sec	Bench Press	4 x 10 reps			
90 sec	Seated Row	4 x 10 reps			
60 sec	DB Press	3 x 10 reps			
60 sec	Lat Pull Down	3 x 10 reps			
30 sec	EZ Curl	3 x 10 reps			
30 sec	Tricep Pushdown	3 x 10 reps			
60 sec	Rotational Crunch	3 x 25 reps			
60 sec	Back Extension	3 x 10 reps			
X	Cardiovascular	25 min			

DAY 2

Rest between Sets			Date	Date	Date
90 sec	DB Incline Press	3 x 10 reps			
90 sec	Front Pull Down	3 x 10 reps			
60 sec	Upright Row	3 x 10 reps			
60 sec	DB Row	3 x 10 reps			
30 sec	DB Curl	3 x 10 reps			
30 sec	DB Tricep	3 x 10 reps			
60 sec	Sit-up	3 x 25 reps			
X	Cardiovascular	25 min			

DAY 3

Rest between Sets			Date	Date	Date
90 sec	Bench Press	4 x 10 reps			
90 sec	Seated Row	4 x 10 reps			
60 sec	DB Press	3 x 10 reps			
60 sec	Lat Pull Down	3 x 10 reps			
30 sec	EZ Curl	3 x 10 reps			
30 sec	Tricep Pushdown	3 x 10 reps			
60 sec	Rotational Crunch	3 x 25 reps			
60 sec	Back Extension	3 x 10 reps			
X	Cardiovascular	25 min			

NAME: _____ **GROUP:** Upper Hyper
TRAINER: _____

DAY 1

Rest between Sets			Date	Date	Date
90 sec	Bench Press	4 x 12 reps			
90 sec	Seated Row	4 x 12 reps			
60 sec	DB Press	3 x 12 reps			
60 sec	Lat Pull Down	3 x 12 reps			
30 sec	EZ Curl	3 x 12 reps			
30 sec	Tricep Pushdown	3 x 12 reps			
60 sec	Rotational Crunch	3 x 25 reps			
60 sec	Back Extension	3 x 12 reps			
X	Cardiovascular	25 min			

DAY 2

Rest between Sets			Date	Date	Date
90 sec	DB Incline Press	3 x 12 reps			
90 sec	Front Pull Down	3 x 12 reps			
60 sec	Upright Row	3 x 12 reps			
60 sec	DB Row	3 x 12 reps			
30 sec	DB Curl	3 x 12 reps			
30 sec	DB Tricep	3 x 12 reps			
60 sec	Sit-up	3 x 25 reps			
X	Cardiovascular	25 min			

DAY 3

Rest between Sets			Date	Date	Date
90 sec	Bench Press	4 x 12 reps			
90 sec	Seated Row	4 x 12 reps			
60 sec	DB Press	3 x 12 reps			
60 sec	Lat Pull Down	3 x 12 reps			
30 sec	EZ Curl	3 x 12 reps			
30 sec	Tricep Pushdown	3 x 12 reps			
60 sec	Rotational Crunch	3 x 25 reps			
60 sec	Back Extension	3 x 12 reps			
X	Cardiovascular	25 min			

NAME: _____ **GROUP:** Upper S/P
TRAINER: _____

DAY 1

Rest between Sets			Date Time In: Out:	Date Time In: Out:	Date Time In: Out:
	Bench Press	3 x 3 reps			
	Seated Row	3 x 5 reps			
	DB Press	3 x 3 reps			
	Lat Pull Down	3 x 6 reps			
	EZ Curl	3 x 6 reps			
	Tri. Push Down	3 x 6 reps			
	Incline Sit-up	3 x 20 reps			
	Back Extension	3 x 8 reps			
X	Cardiovascular	25 min			

DAY 2

Rest between Sets			Date Time In: Out:	Date Time In: Out:	Date Time In: Out:
	DB Incline Press	3 x 3 reps			
	Front Pull Down	3 x 6 reps			
	Upright Row	3 x 5 reps			
	DB Row	3 x 5 reps			
	DB Curl	3 x 6 reps			
	DB Tricep	3 x 6 reps			
	Crunch	3 x 25 reps			
X	Cardiovascular	25 min			

DAY 3

Rest between Sets			Date Time In: Out:	Date Time In: Out:	Date Time In: Out:
	Bench Press	3 x 3 reps			
	Seated Row	3 x 5 reps			
	DB Press	3 x 3 reps			
	Lat Pull Down	3 x 6 reps			
	EZ Curl	3 x 6 reps			
	Tri. Push Down	3 x 6 reps			
	Weighted Sit-up	3 x 8 reps			
	Back Extension	3 x 10 reps			
X	Cardiovascular	25 min			

NAME: _____ **GROUP:** Upper S/P
TRAINER: _____

DAY 1

	Rest between Sets		Date			Date			Date		
	Bench Press	3 x 5 reps									
	Seated Row	3 x 5 reps									
	DB Press	3 x 5 reps									
	Lat Pull Down	3 x 8 reps									
	EZ Curl	3 x 8 reps									
	Tri. Push Down	3 x 8 reps									
	Incline Sit-up	3 x 20 reps									
	Back Extension	3 x 10 reps									
X	Cardiovascular	25 min									

DAY 2

	Rest between Sets		Date			Date			Date		
	DB Incline Press	3 x 5 reps									
	Front Pull Down	3 x 8 reps									
	Upright Row	3 x 5 reps									
	DB Row	3 x 5 reps									
	DB Curl	3 x 8 reps									
	DB Tricep	3 x 8 reps									
	Crunch	3 x 25 reps									
X	Cardiovascular	25 min									

DAY 3

	Rest between Sets		Date			Date			Date		
	Bench Press	3 x 5 reps									
	Seated Row	3 x 5 reps									
	DB Press	3 x 5 reps									
	Lat Pull Down	3 x 8 reps									
	EZ Curl	3 x 8 reps									
	Tri. Push Down	3 x 8 reps									
	Weighted Sit-up	3 x 10 reps									
	Back Extension	3 x 10 reps									
X	Cardiovascular	25 min									

NAME: _____ **GROUP:** Upper S/P
TRAINER: _____

DAY 1

	Rest between Sets		Date			Date			Date		
	Bench Press	3 x 8 reps									
	Seated Row	3 x 8 reps									
	DB Press	3 x 8 reps									
	Lat Pull Down	3 x 8 reps									
	EZ Curl	3 x 8 reps									
	Tri. Push Down	3 x 8 reps									
	Incline Sit-up	3 x 20 reps									
	Back Extension	3 x 8 reps									
X	Cardiovascular	25 min									

DAY 2

	Rest between Sets		Date			Date			Date		
	DB Incline Press	3 x 8 reps									
	Front Pull Down	3 x 8 reps									
	Upright Row	3 x 8 reps									
	DB Row	3 x 8 reps									
	DB Curl	3 x 8 reps									
	DB Tricep	3 x 8 reps									
	Crunch	3 x 25 reps									
X	Cardiovascular	25 min									

DAY 3

	Rest between Sets		Date			Date			Date		
	Bench Press	3 x 8 reps									
	Seated Row	3 x 8 reps									
	DB Press	3 x 8 reps									
	Lat Pull Down	3 x 8 reps									
	EZ Curl	3 x 8 reps									
	Tri. Push Down	3 x 8 reps									
	Weighted Sit-up	3 x 8 reps									
	Back Extension	3 x 8 reps									
X	Cardiovascular	25 min									

NAME: _____ **GROUP:** Total Hyper
TRAINER: _____

DAY 1

Rest between Sets		Date Time In:	Out:	Date Time In:	Out:	Date Time In:	Out:
60 sec	Squat	3 x 8 reps					
30 sec	Leg Extension	3 x 8 reps					
30 sec	Leg Curl	3 x 8 reps					
60 sec	DB Incline Press	3 x 8 reps					
60 sec	Chest Fly	3 x 8 reps					
60 sec	Front Pull Down	3 x 8 reps					
30 sec	Upright Row	3 x 8 reps					
30 sec	DB Row	3 x 8 reps					
60 sec	Rotational Crunch	3 x 25 reps					
X	Cardiovascular	25 min					

DAY 2

Rest between Sets		Date Time In:	Out:	Date Time In:	Out:	Date Time In:	Out:
30 sec	Leg Extension	3 x 8 reps					
30 sec	Leg Curl	3 x 8 reps					
30 sec	Heel Raise	3 x 8 reps					
60 sec	Bench Press	3 x 8 reps					
60 sec	Seated Row	3 x 8 reps					
30 sec	Tri. Push Down	3 x 8 reps					
30 sec	EZ Curl	3 x 8 reps					
60 sec	Sit-up	3 x 25 reps					
X	Cardiovascular	25 min					

DAY 3

Rest between Sets		Date Time In:	Out:	Date Time In:	Out:	Date Time In:	Out:
60 sec	Squat	3 x 8 reps					
30 sec	Leg Curl	3 x 8 reps					
30 sec	Heel Raise	3 x 8 reps					
60 sec	Nar. Bench Press	3 x 8 reps					
30 sec	DB Row	3 x 8 reps					
30 sec	DB Tricep	3 x 8 reps					
30 sec	DB Curl	3 x 8 reps					
60 sec	Crunch	3 x 25 reps					
X	Cardiovascular	25 min					

NAME: _____ **GROUP:** Total Hyper
TRAINER: _____

DAY 1

Rest between Sets		Date			Date			Date		
90 sec	Squat	3 x 10 reps								
60 sec	Leg Extension	3 x 10 reps								
60 sec	Leg Curl	3 x 10 reps								
60 sec	DB Incline Press	3 x 10 reps								
60 sec	Chest Fly	3 x 10 reps								
60 sec	Front Pull Down	3 x 10 reps								
30 sec	Upright Row	3 x 10 reps								
30 sec	DB Row	3 x 10 reps								
60 sec	Rotational Crunch	3 x 25 reps								
X	Cardiovascular	25 min								

DAY 2

Rest between Sets		Date			Date			Date		
90 sec	Leg Extension	3 x 10 reps								
90 sec	Leg Curl	3 x 10 reps								
60 sec	Heel Raise	3 x 10 reps								
90 sec	Bench Press	3 x 10 reps								
90 sec	Seated Row	3 x 10 reps								
30 sec	Tri. Push Down	3 x 10 reps								
30 sec	EZ Curl	3 x 10 reps								
60 sec	Sit-up	3 x 25 reps								
X	Cardiovascular	25 min								

DAY 3

Rest between Sets		Date			Date			Date		
90 sec	Squat	3 x 10 reps								
60 sec	Leg Curl	3 x 10 reps								
60 sec	Heel Raise	3 x 10 reps								
90 sec	Nar. Bench Press	3 x 10 reps								
90 sec	DB Row	3 x 10 reps								
30 sec	DB Tricep	3 x 10 reps								
30 sec	DB Curl	3 x 10 reps								
60 sec	Crunch	3 x 25 reps								
X	Cardiovascular	25 min								

NAME: _____ **GROUP:** Total Hyper
TRAINER: _____

DAY 1

Rest between Sets		Date	Date	Date
90 sec	Squat	3 x 12 reps			
60 sec	Leg Extension	3 x 12 reps			
60 sec	Leg Curl	3 x 12 reps			
60 sec	DB Incline Press	3 x 12 reps			
60 sec	Chest Fly	3 x 12 reps			
60 sec	Front Pull Down	3 x 12 reps			
30 sec	Upright Row	3 x 12 reps			
30 sec	DB Row	3 x 12 reps			
60 sec	Rotational Crunch	3 x 25 reps			
X	Cardiovascular	25 min			

DAY 2

Rest between Sets		Date	Date	Date
90 sec	Leg Extension	3 x 12 reps			
90 sec	Leg Curl	3 x 12 reps			
60 sec	Heel Raise	3 x 12 reps			
90 sec	Bench Press	3 x 12 reps			
90 sec	Seated Row	3 x 12 reps			
30 sec	Tri. Push Down	3 x 12 reps			
30 sec	EZ Curl	3 x 12 reps			
60 sec	Sit-up	3 x 25 reps			
X	Cardiovascular	25 min			

DAY 3

Rest between Sets		Date	Date	Date
90 sec	Squat	3 x 12 reps			
60 sec	Leg Curl	3 x 12 reps			
60 sec	Heel Raise	3 x 12 reps			
90 sec	Nar. Bench Press	3 x 12 reps			
90 sec	DB Row	3 x 12 reps			
30 sec	DB Tricep	3 x 12 reps			
30 sec	DB Curl	3 x 12 reps			
60 sec	Crunch	3 x 25 reps			
X	Cardiovascular	25 min			

NAME: _____ **GROUP:** Total S/P
TRAINER: _____

DAY 1

Rest between Sets		Date Time In: Out:	Date Time In: Out:	Date Time In: Out:
DB Clean & Press	3 x 3 reps			
Leg Curl	3 x 6 reps			
DB Incline Press	3 x 3 reps			
Front Pull Down	3 x 6 reps			
Squat	3 x 3 reps			
Incline Sit-up	3 x 15 reps			
Upright Row	3 x 5 reps			
DB Row	3 x 5 reps			
X Cardiovascular	25 min			

DAY 2

Rest between Sets		Date Time In: Out:	Date Time In: Out:	Date Time In: Out:
High Pull	3 x 3 reps			
Leg Curl	3 x 6 reps			
Bench Press	3 x 3 reps			
Seated Row	3 x 5 reps			
DB Press	3 x 3 reps			
Lat Pull Down	3 x 6 reps			
Heel Raise	3 x 8 reps			
Crunch	3 x 25 reps			
X Cardiovascular	25 min			

DAY 3

Rest between Sets		Date Time In: Out:	Date Time In: Out:	Date Time In: Out:
High Pull	3 x 3 reps			
Weighted Sit-up	3 x 10 reps			
Squat	3 x 3 reps			
Heel Raise	3 x 8 reps			
Nar. Bench Press	3 x 3 reps			
DB Row	3 x 5 reps			
Leg Extension	3 x 6 reps			
Leg Curl	3 x 6 reps			
X Cardiovascular	25 min			

NAME: _____ **GROUP:** Total S/P
TRAINER: _____

DAY 1

Rest between Sets			Date			Date			Date		
	DB Clean & Press	3 x 5 reps									
	Leg Curl	3 x 8 reps									
	DB Incline Press	3 x 5 reps									
	Front Pull Down	3 x 8 reps									
	Squat	3 x 5 reps									
	Incline Sit-up	3 x 15 reps									
	Upright Row	3 x 8 reps									
	DB Row	3 x 8 reps									
X	Cardiovascular	25 min									

DAY 2

Rest between Sets			Date			Date			Date		
	High Pull	3 x 5 reps									
	Leg Curl	3 x 8 reps									
	Bench Press	3 x 5 reps									
	Seated Row	3 x 5 reps									
	DB Press	3 x 5 reps									
	Lat Pull Down	3 x 8 reps									
	Heel Raise	3 x 8 reps									
	Crunch	3 x 25 reps									
X	Cardiovascular	25 min									

DAY 3

Rest between Sets			Date			Date			Date		
	High Pull	3 x 5 reps									
	Weighted Sit-up	3 x 10 reps									
	Squat	3 x 5 reps									
	Heel Raise	3 x 8 reps									
	Nar. Bench Press	3 x 5 reps									
	DB Row	3 x 5 reps									
	Leg Extension	3 x 8 reps									
	Leg Curl	3 x 8 reps									
X	Cardiovascular	25 min									

NAME: _____ **GROUP:** Total S/P
TRAINER: _____

DAY 1

Rest between Sets			Date			Date			Date		
	DB Clean & Press	3 x 8 reps									
	Leg Curl	3 x 8 reps									
	DB Incline Press	3 x 8 reps									
	Front Pull Down	3 x 8 reps									
	Squat	3 x 8 reps									
	Incline Sit-up	3 x 15 reps									
	Upright Row	3 x 8 reps									
	DB Row	3 x 8 reps									
X	Cardiovascular	25 min									

DAY 2

Rest between Sets			Date			Date			Date		
	High Pull	3 x 8 reps									
	Leg Curl	3 x 8 reps									
	Bench Press	3 x 8 reps									
	Seated Row	3 x 8 reps									
	DB Press	3 x 8 reps									
	Lat Pull Down	3 x 8 reps									
	Heel Raise	3 x 8 reps									
	Crunch	3 x 25 reps									
X	Cardiovascular	25 min									

DAY 3

Rest between Sets			Date			Date			Date		
	High Pull	3 x 8 reps									
	Weighted Sit-up	3 x 8 reps									
	Squat	3 x 8 reps									
	Heel Raise	3 x 8 reps									
	Nar. Bench Press	3 x 8 reps									
	DB Row	3 x 8 reps									
	Leg Extension	3 x 8 reps									
	Leg Curl	3 x 8 reps									
X	Cardiovascular	25 min									

APPENDIX 2

Preliminary Assay Work Ups on Growth Hormone

GOAL: To determine the effect of acute vs. chronic exercise training in human females on the concentration, molecular size and biological activity of circulating growth hormone (GH).

RATIONALE: Approximately 15 molecular variants of GH are contained within the human pituitary gland. Some of these are released into the circulation. Many escape detection by standard immunological assays (RIA). Some may influence (regulate) activity of different body systems; e.g. musculoskeletal and immune cells. In addition to the RIA we have chosen two biological assays to monitor the effects of exercise on circulating GH. One is an in vitro test using a rat T lymphocyte cell line; the other measures restoration of bone growth in a rat which has stopped growing because its pituitary gland has been surgically removed.

METHODS: Plasma fractionation by G-100 sephadex chromatography prior to measurement of GH . Fraction A contuse molecules with apparent molecular weight >60 kD; fraction B 60-30 kD; fraction C <30kD. Assays: RIA using a monoclonal antibody to GH; the Nb2 lymphocyte proliferation assay of Tanaka(1980) and the tibial line bioassay of Greenspan(1948) which measures growth of long bones in the hypophysectomized rat.

RESULTS: The average concentrations of (a) immunoreactive (iGH); (b) tibial active (t-GH)and (c) lymphocyte active (l-GH) in the unfractionated (start). large (Fr. A), middle (Fr.B) and low (Fr C) molecular weight ranges in pre-exercise plasmas of 17 subjects is shown in Fig. 1. Note that an order of magnitude more GH is detected by tibial assay. When expressed on a percentage basis, these concentrations show 3 different results that are assay dependent. Thus, by RIA most of the GH is distributed equally between molecules of mid and small size range (Fig. 2). On the other hand most of the t-GH activity is recovered in the large and mid molecular size range. Finally, l-GH predominates in FrC. Post exercise data (Figs. 3 and 4) show some differences. These arebest seen by direct comparisons of the percentage changes from pre to post exercise (Fig. 5). These comparisons show (a) that exercise increases the concentration of GH in unfractionated plasma regardless of the assay used; (b) that exercise increases the size of circulating iGH molecules (evidenced by the % change in frs. A and B vs. C); (c) that exercise decreases t-GH in the molecular weight range of 30 - 60 kD apparently at the expense of increases in Fr. C and finally (d)that GH measured by lymphocyte activity is primarily associated with large molecules (Fr. A).

CONCLUSIONS: (1) Acute exercise increases the concentration of circulating GH as measured by 3 different assays.

(2) Acute exercise does not change the sizes of immunoreactive and bioreactive GH in any uniform way

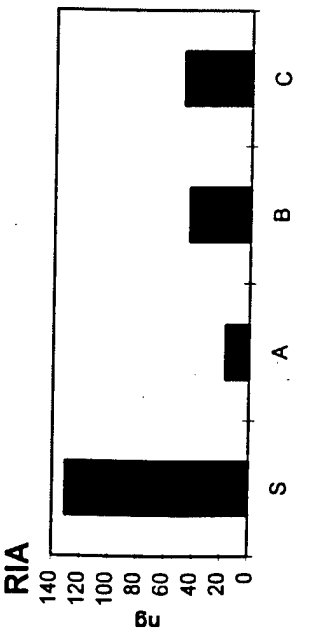
(3) Acute exercise increases aggregation of iGH molecules but does not increase aggregation of GH molecules active in the bone growth assay.

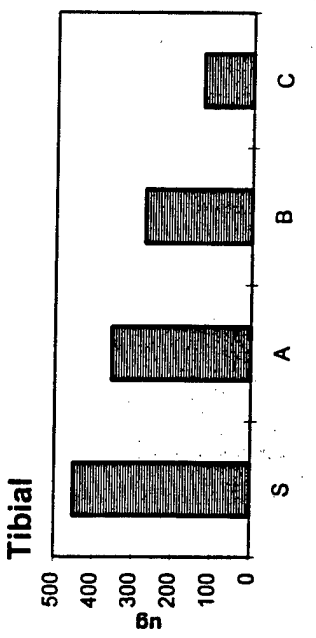
These results imply that measurement of GH by standard RIA techniques will not yield data that are likely to predict a biological outcome with certainty. They point to the wisdom of measuring concentrations of circulating GH using biological rather than immunological endpoints. The results of the T3 phase of our study will be available by the end of 1997.

Figure 1

Pre-exercise

GH per 15 ml plasma





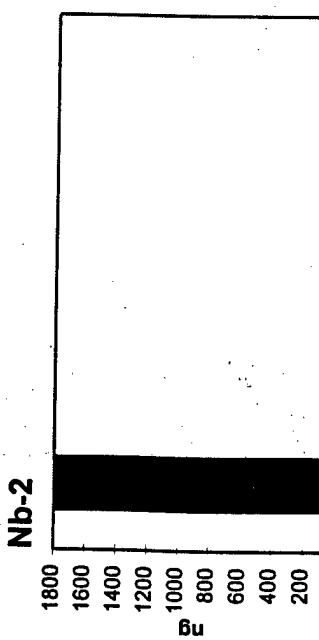
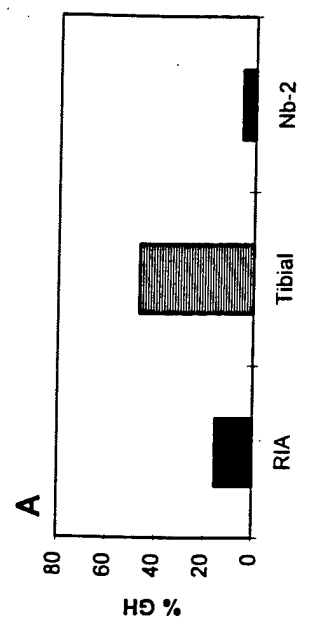
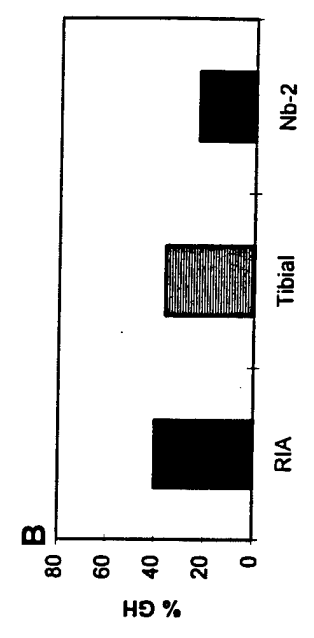


Figure 2

% recovered GH in fractions





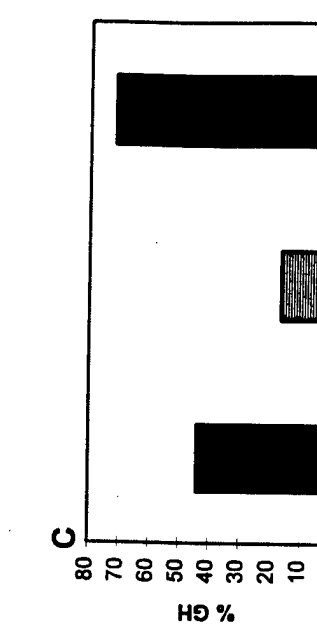


Figure 3

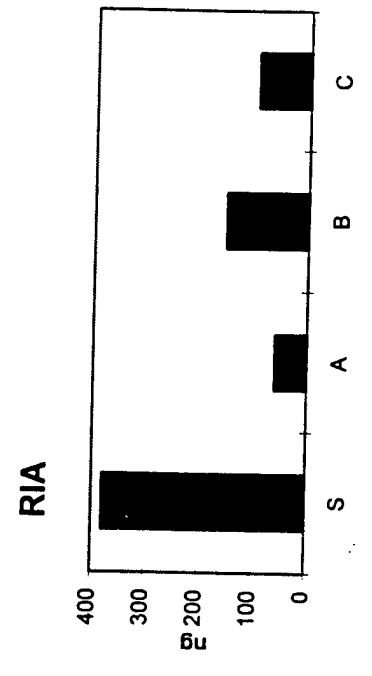


Figure 4

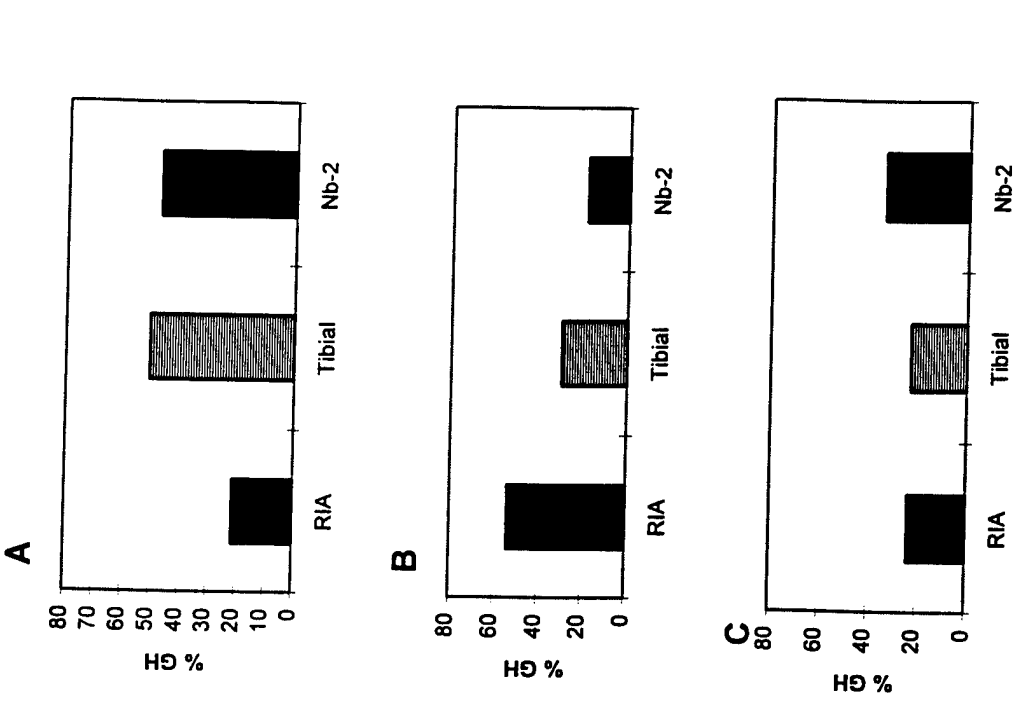
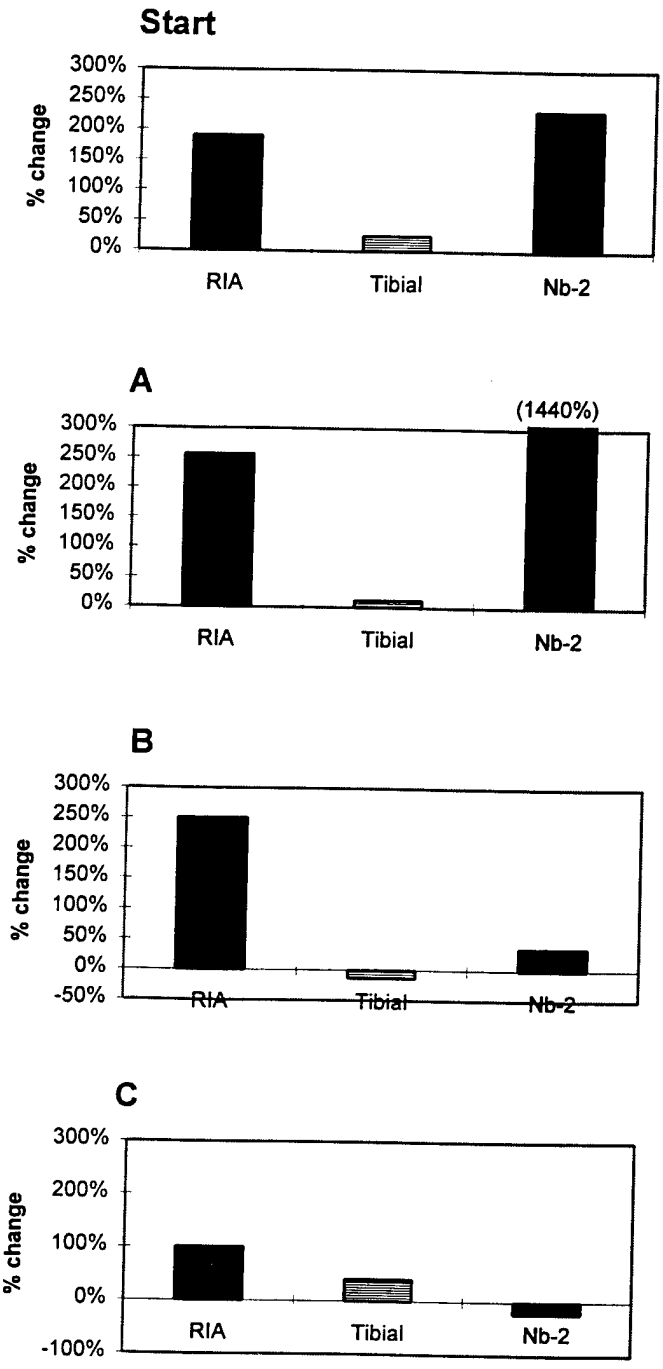
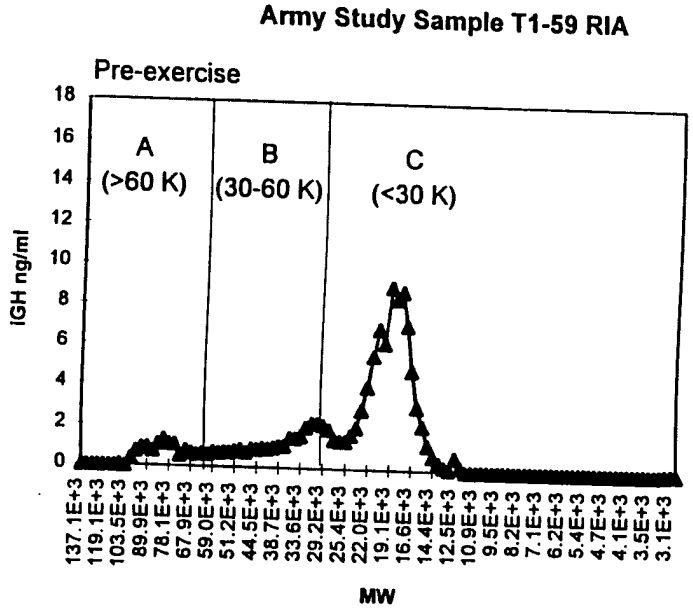
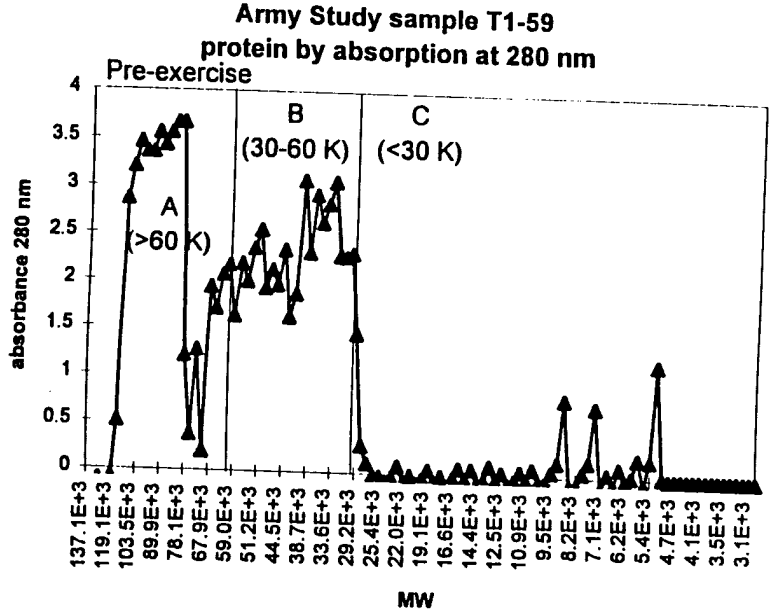


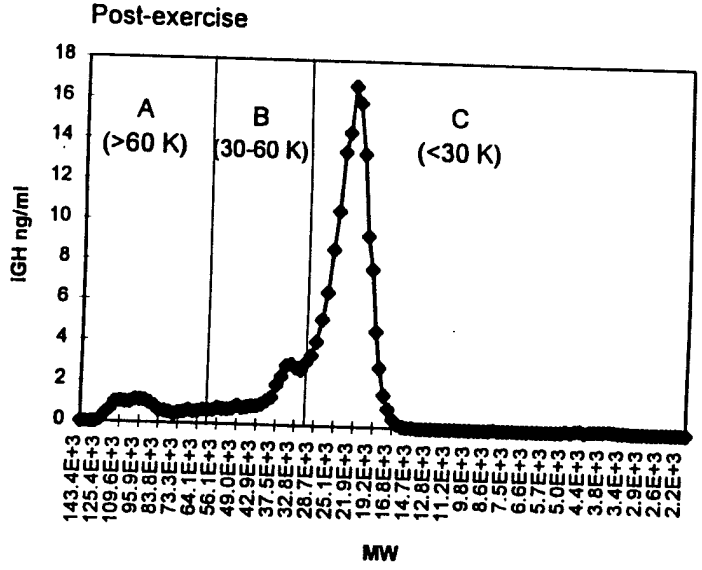
Figure 5

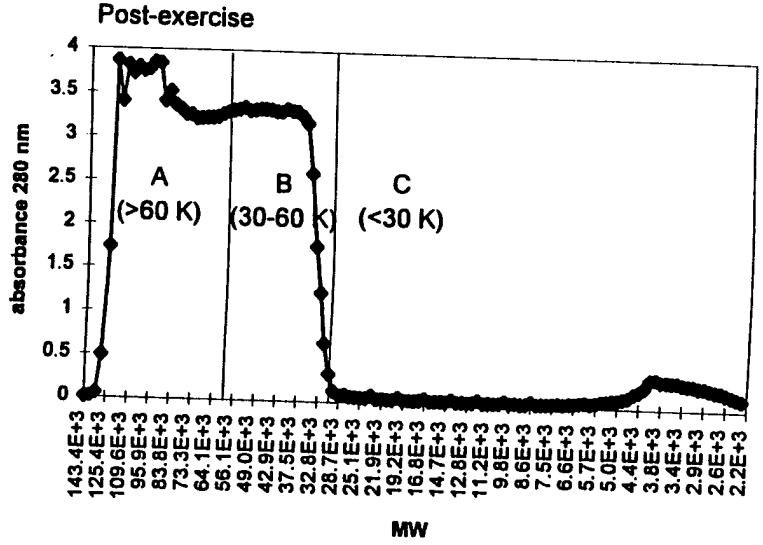
Percent change from Pre to Post




Army Study Sample T1-59 RIA
Pre-exercise
A
(>60 K)
B
(30-60 K)
C
(<30 K)
IGH ng/ml
MW


Army Study sample T1-59
protein by absorption at 280 nm
Pre-exercise
A
(>60 K)
B
(30-60 K)
C
(<30 K)
absorbance 280 nm
MW


Post-exercise
A
(>60 K)
B
(30-60 K)
C
(<30 K)
IGH ng/ml
MW


Post-exercise
A
(>60 K)
B
(30-60 K)
C
(<30 K)
absorbance 280 nm
MW

APPENDIX 3

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GROWTH HORMONE AND INSULIN-LIKE GROWTH FACTOR 1 RESPONSES TO ACUTE RESISTANCE EXERCISE IN UNTRAINED WOMEN B.C. Nindl, L.A. Gotshalk, J.S. Volek, F.S. Harman, S.A. Tokeshi,S.A. Mazzetti, C.C. Loebel, J.O. Marx, S.E. Gordon, N.D. Duncan, W.C. Hymer, M. Putukian, W.J. Sebastianelli and W.J. Kraemer (SPON: W.J. Kraemer).Ctr for Cell Resch, Ctr for Sports Med and Noll Physiol Resch Ctr, Penn State Univ, University Park, PA, 16802

While serum growth hormone (GH) increases with exercise have been consistently observed, serum insulin-like growth factor 1 (IGF-1) responses have been equivocal. In addition, little is known about IGF-1 responses in women after acute resistance exercise. The purpose of this study was to examine serum GH, IGF-1 and lactate responses to an acute resistance exercise protocol (RE) among 47 women (22±3 yr.; 165±6 cm; 62±8 kg; 25±5 %BF). Venous blood was obtained from subjects via pre- and post-RE (6 sets of 10RM squats separated by 2 min). Serum GH and IGF-1 concentrations were then determined by radioimmunoassay. The RE resulted in significant ($p \leq .05$) increases in lactate (2.1±.8 vs. 10.4±3.2 mmol/L) and GH (4.9±6.3 vs. 16.6±8.8 µg/L), but not in IGF-1 (36.4±9 vs. 38.0±8.4 nmol/L). Individual IGF-1 responses, however, were highly variable with changes ranging from -40% to +49%. Tertiles based on these %Δs in IGF-1 revealed a 13±9% decrease (40.8±10 vs. 35.0±6 nmol/L) in tertile 1 and a 27±10% increase (31.0±8 vs. 39.6±10 nmol/L) in tertile 3; pre-IGF-1 values between these tertiles also differed. IGF-1 %Δs were not correlated with pre-exercise GH or %ΔGH values but were negatively correlated with pre-exercise IGF-1 values (r= -.51). These data confirm the independence of IGF-1 exercise responses from immunoreactive GH, and also suggest that pre-exercise values of IGF-1 may be a factor associated with the potential IGF-1 response to exercise in women. *DOD US Army Grant DAMD 17-95-C-5069*

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TESTOSTERONE AND SHBG RESPONSES TO ACUTE RESISTANCE EXERCISE IN YOUNG HEALTHY WOMEN: EFFECTS OF REGIONAL FAT DISTRIBUTION.

B.C. Nindl, L.A. Gotshalk, S.A. Mazzetti, C.C. Loebel, J. Volek, F.S. Harman, K.Hakkinen, M.Putukian, FACSM and W.J. Kraemer, FACSM. Ctr for Sports Med, Dept of Kines, Noll Physiol Res Ctr, Penn State University, University Park, PA (Sponsor: W.J. Kraemer)

Regional fat distribution (RFD) has been associated with metabolic derangements in populations with obesity (e.g. upper body fat patterning is associated with higher levels of free testosterone (FT) and lower levels of sex-hormone binding globulin (SHBG)). The extent to which this relationship is true in healthy female populations and whether RFD influences androgen responses to resistance exercise has not been fully described. This study examined the effects of RFD on total testosterone (TT), FT, and SHBG responses to an acute resistance exercise test (ARET) among 47 women (22 ± 3 yr.; 165 ± 6 cm; 62 ± 8 kg; 25 ± 5 %BF; 23 ± 3 BMI). RFD was characterized by 2 separate indices: waist-to-hip ratio (WHR) and ratio of upper arm fat to mid-thigh fat (ALFATR) assessed via magnetic resonance imaging. The ARET consisted of 6 sets of 10RM squats separated by 2 min rest periods. Blood was obtained via venipuncture pre and post the ARET. TT, FT, and SHBG concentrations were determined by radioimmunoassay. Subjects were divided into tertiles from the indices of RFD and statistical analyses were performed via an ANOVA with repeated measures (RFD and exercise as main effects). Significant ($p \leq .05$) group effects existed for ALFATR, but not WHR. This indicated that women with upper body fat patterning possessed higher concentrations of FT (7.33 vs. 10.81 pmol/L for ALFATR tertiles 1 and 3 respectively). Main effects were observed for exercise demonstrating that the ARET served as a potent stimulus for acute increases in TT (1.24 vs. 1.55 nmol/L;~25% rise), FT (~24% rise) and SHBG (~4%).We conclude that for young healthy women: 1) resistance exercise can induce transient increases in androgen levels and 2) the use of ALFATR may be more discriminant than the WHR for assessing metabolic profiles associated with RFD.

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PREDICTION OF REPETITVE LIFTING ABILITY IN UNTRAINED WOMEN FROM MUSCULAR STRENGTH AND ENDURANCE

S. Meth, B.C. Nindl, L.A. Gotshalk, C.C. Loebel, S.A. Mazzetti, S.J. Fleck, R.U. Newton and W.J. Kraemer, FACSM, Ctr for Sports Med, Dept of Kines, and Noll Physio Research Ctr, Penn State University, University Park, PA (Sponsor:W.J. Kraemer, FACSM)

The relationship between characteristics of muscular performance (e.g. size, strength, power, endurance) and occupational tasks has not been clearly defined. This study assessed the physical performance of 47 untrained women (22 ± 3 yr; 165 ± 6 cm; 62 ± 8 kg; 25 ± 5 %BF) and identified via multiple regression analysis the best predictors of a repetitive lifting test (RLT). The RLT consisted of the maximum number of boxes (20.45 kg) that could be lifted from the floor to a height of 132 cm within a 10 min period (subjects were required to move between two boxes 2.4 m apart between lifts). Independent variables (IVs) included weight (wt), height (ht), MRI assessed arm and leg cross-sectional area, muscular strength 1RMs (bench press, squat, high pull, boxlift), upper and lower body explosive power (mechanical power determined from bench press throws and jump squats), muscular endurance (# of push-ups in 2 min and # of squat repetitions at a controlled rate with a 45 kg load) and aerobic capacity assessed from a 2 mile run (2MR in secs). The mean ±SD (range) for the RLT was : 92±25(20-159). For all IVs (excluding the 2MR) the following equation was generated : RLT (#) = 2.4(1RM boxlift in kg) + 0.70 (# of push-ups in 2 min) + 0.94 (Ht) - 146 [R= 0.83; SEE = 15; p≤0.05]. When 2MR was included, the equation was: RLT (#) = 2.9(1RM boxlift in kg) - 0.05 (2MR in secs) + 73 [R = 0.83; SEE = 14; p≤0.05]. Because the 1RM boxlift correlated higher than any of the other variables (r = 0.74) with RLT and entered into both equations, these results illustrate the importance of task-specific strength for predicting successful job performance. Also, the predictive value of a measure of aerobic capacity for RLT suggests that women can also benefit from endurance training for repetitive occupational tasks requiring total body strength and local muscular and aerobic endurance.

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RELATIONSHIP BETWEEN THIGH MORPHOLOGY AND STRENGTH AND POWER PERFORMANCE IN YOUNG WOMEN

L.A. Gotshalk, B.C. Nindl, C.C. Loebel, J.S. Volek, S. Tokeshi, and W.J. Kraemer, FACSM. Ctr for Sports Med, Dept of Kines, Noll Phy Res Ctr Penn State University, UniversityPark, PA (Sponsor: W.J.Kraemer, FACSM)

To compare how thigh cross sectional areas (CSAs) of individual muscles and whole muscle groups are related to strength versus power performances in young women, magnetic resonance imaging (MRI) was performed on the dominant thighs of 42 young women (22.4± yrs, 164.5±6.3 cm, 61.73±7.3 kg; 24.6 ±5.3% BF) and muscle strength and power measurements were obtained using the identical testing equipment. An MRI axial scan 50% of the distance between the superior border of the head of the trochanter to the inferior border of the femoral condyle was used for CSA analysis. Strength was assessed using a 1-repetition maximum (1-RM) squat (SQ) and power was assessed using a maximal jump squat (JSQ) with 30% of 1-RM squat on a computerized Plyometric Power System. Mean maximums were, for SQ: 52.53±12.68kg; for JSQ: 1666.56±322.85W. The results indicated that force and power production in general in untrained women is not well predicted by any individual thigh muscle CSA. Body mass, lean thigh muscle CSA, and quadriceps CSA all correlated with both strength and power performances. Body mass had a more predictive role in power (r^2=.50) than in strength (r^2=.09), as did lean muscle mass (r^2=.49 vs .27) and quadriceps (r^2=.65 vs .37). The hamstrings CSA did not correlate to the 1-RM SQ, but correlated to the JSQ power. The fact that the hamstrings CSA did not correlate with the 1-RM squat but did relate highly with the JSQ ($p<0.001$, r^2=.43) indicates that their role is more important in hip extension power production than it is in hip extension strength production. It is possible that the forceful terminal hip extension required for the JSQ demands more from the hamstrings as extensors, which increase their force production on the hip as the knee extends. It is concluded that a large neural component often factored out by training, is responsible for masking the predictive ability of thigh muscle CSA for strength, lesser so for power in untrained women.

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1689 PLASMA CORTISOL ELEVATION ON LYMPHOCYTE PROLIFERATION RESPONSE TO MITOGENS AFTER ACUTE RESISTANCE EXERCISE IN WOMEN

K. Dohi, A. M. Mastro, M. P. Miles, J.A. Bush, M. Putukian, FACSM, and W. J. Kraemer, FACSM, Center for Sports Med., Dept. Kines., Noll Physiol. Res. Ctr. and Center for Cell Research, The Pennsylvania State University, University Park, PA. 16802.
(Sponsor, W.J. Kraemer, FACSM)

In order to examine the effects of high (>1000 nmol·L^{-1}) and low (<500 nmol·L^{-1}) concentrations of cortisol on lymphocyte proliferation after acute heavy resistance exercise, 8 high (23.5 ± 3.2 yrs) and 8 low (22.1 ± 3.4 yrs) responders were studied from a population of 46 healthy but non-strength trained women. The resistance exercise test consisted of performing six sets of 10 repetition maximum (RM) squats with 2 minutes rest between sets utilizing a computerized Plyometic Power System. Blood samples were obtained at pre-exercise and immediately post exercise. Lymphocyte responses to pokeweed mitogen (PWM) were determined through the incorporation of triated thymidine. Plasma cortisol was measured via standard solid phase RIA techniques. The squat exercise significantly decreased lymphocyte proliferation response to PWM in high cortisol concentration group (29616 to 20190 CPM: $p \leq 0.05$) but not in low cortisol concentration group (33326 to 31990 CPM:$p > 0.05$). The data indicate plasma cortisol elevation during the exercise may be associated with the decreased lymphocyte T and B cell proliferation response. Thus the exercise-induced cortisol elevation may partially explain the mechanism of immuno suppression that might result in susceptible to pathogens immediately after the heavy resistance exercise training session.

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EXERCISE-INDUCED TRAFFICKING VIA L-SELECTIN AND VLA-4 INTEGRIN DIFFERS BETWEEN LYMPHOCYTES AND NEUTROPHILS

M.P. Miles, S.K. Leach, K. Dohi, J.A. Bush, A.M. Mastro, and W.J. Kraemer, FACSM. Penn State University, University Park, PA (Sponsor: W.J. Kraemer, FACSM)

L-selectin and VLA-4 integrin are adhesion molecules that influence trafficking and homing of leukocytes. The mechanism underlying exercise-induced fluctuations in lymphocytes and neutrophils involves surface adhesion molecules, however, the roles of L-selectin and VLA-4 integrin have not been determined. It is known that VLA-4 integrin is not typically expressed on neutrophils. The aim of this study was 1) to determine whether expression of L-selectin and VLA-4 integrin are altered by exercise; and 2) to compare trafficking of lymphocytes and neutrophils with respect to these molecules. Blood samples from 29 females were collected immediately before and after performance of 6 sets of 10 repetition maximum squats, a high-intensity, anaerobic exercise lasting about 20 minutes. Expression of L-selectin and VLA-4 integrin were determined with flow cytometry using FITC conjugated CD62L and PE conjugated CD49d monoclonal antibodies, respectively. Lymphocytes increased ($p<0.001$) by 1.71×10^9 cells$\cdot l^{-1}$, of which 1.14×10^9 cells$\cdot l^{-1}$ were CD49d+ and 0.37×10^9 cells$\cdot l^{-1}$ were CD62L+. Neutrophils increased ($p<0.001$) by 1.43×10^9 cells$\cdot l^{-1}$, all of which were CD62L+. The fluorescence intensity of CD62L+ neutrophils increased ($p<0.05$), indicating increased expression of L-selectin during exercise. Thus, it is concluded that while the VLA-4 integrin may be involved in lymphocyte recruitment to the circulation during exercise, L-selectin plays a less crucial role. Conversely, while increased L-selectin expression can account for all of the neutrophils recruited to the circulation, VLA-4 integrin, as expected, played no role in this process.

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COMPARISON OF ABSOLUTE STRENGTH VS ABSOLUTE OCCUPATIONAL LIFTING PERFORMANCE IN UNTRAINED MEN AND WOMEN

S. Meth, B.C. Nindl, L.A. Gotshalk, C.C. Loebel, N.D. Duncan, S.A. Tokeshi, M.Putukian, W.J. Sebastianelli, K.Häkkinen, and W.J. Kraemer. Center for Sports Medicine, Dept of Kinesiology, Noll Physiological Research Center, Penn State University, University Park, PA. 16802.

It is well established that, on average, men have a higher absolute strength than women. However, how the magnitude difference in muscular strength compares to the magnitude difference in occupational lifting performance (OLP) and whether men (M) and women (W) exhibit the same relationship between static measures of physical performance and dynamic OLP is unknown. This study compared the magnitude of absolute differences in strength (i.e. bench press [BP], squat [SQ], 1 RM boxlift from floor to 132 cm.[BL]), and aerobic capacity (2 mile run time [2MRT]), to OLP in 56 men (23±3 yrs, 177± 6 cm, 82±16 kg, 15±5 %BF) and 120 women (23±4 yrs, 166±7 cm, 64±10 kg, 25±5 %BF). OLP was calculated as total work (J) performed in 10 minutes by repetitively lifting a 20.5 kg metal box (47 cm x 23 cm x 31 cm) from the floor to a height of 132 cm (subjects were required to move between two boxes 2.4 m apart between lifts). M had significantly ($p \leq 0.05$) higher values than W (% difference between M & W is given in[]) for BP (87±21 vs. 32±7 kg; [63%]), SQ (108±26 vs. 52±12 kg; [52%]), BL (62±12 vs 30±5 kg [39%]), 2MRT (964±164 vs. 1214±231 secs; [26%]) and OLP (37163±5626 vs. 22704±6187 J; [39%]). Moderate correlations ($p \leq 0.05$) were observed for M and W between BP (M: r=0.49; W: r=0.56), SQ (M: r=0.45; W: r=0.48), BL (M: r=0.41; W: r=0.54), 2MRT (M: r=-0.54; W: -0.54) and OLP. We conclude that the relative gender difference in OLP requiring both strength and endurance is *less* than what is observed between men and women for 1RM strength measures.

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PROLACTIN RESPONSES TO ACUTE RESISTANCE EXERCISE IN UNTRAINED WOMEN: RELATIONSHIP TO CORTISOL AND TESTOSTERONE

C.C. Loebel, B.C. Nindl, L.A. Gotshalk, S. Meth, A. Mastro, M. Putukian, W.J. Sebastianelli, K. Häkkinen, N.D. Duncan and W.J. Kraemer. Ctr for Sports Med, Dept of Kines, Noll Physiol Res Ctr, Penn State Univ., University Park, PA 16802

Prolactin (PRL) is a stress hormone secreted by the anterior pituitary gland which may impact cortisol (CORT) and testosterone (TEST) release. Prior research has focused on the effects of aerobic exercise on PRL, however, few data exist regarding resistance exercise. This study determined the effect of an acute resistance exercise test (ARET) on PRL responses and its relationship to CORT and TEST responses. Venous blood was obtained from forty-seven eumenorrheic women (22 ± 3 yr.; 165 ± 6 cm; 62 ± 8 kg; 25 ± 5 %BF) pre and post an ARET (6 sets of 10RM squats separated by 2 min rest periods). Radioimmunoassays determined PRL, TEST, and CORT concentrations. Results demonstrated significant ($p \leq 0.05$) elevations (mean±SE) in PRL (15±1 vs. 25±2 µg/L), TEST (1.2±0.1 vs. 1.5±0.1 nmol/L), CORT (838±64 vs. 914±62 nmol/L), and lactate (LACT) (2.1±0.1 vs. 10.4±0.5 mmol/L). Pre PRL concentrations were significantly correlated with %Δ CORT (r=-0.30) and %Δ PRL (r=-0.30) but not %Δ T (r=0.07) or %Δ L (r=-0.02). In addition, %Δ PRL was correlated with %Δ C (r=0.75) and %Δ L (r=0.33) but not %Δ T (r=0.18). These results indicate that in untrained women, PRL is more responsive to resistance exercise than TEST or CORT. Also, resting basal PRL and %Δ PRL responses are more highly associated with CORT than TEST. The association between %Δ PRL and %Δ L support previous data suggesting a link between exercise intensity and PRL release. PRL responses to resistance exercise may be a useful marker for quantifying the overall intensity of the exercise performed.

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