Thesis Proposal

Team BALANCE

Mentor: Dr. Jae K. Shim

I pledge on my honor that I have not given or received any unauthorized assistance on this assignment.

Mengge Shan	**Christine Muscolo**	**Adina Schwartz**
______________	______________	______________
Jared Lindenberg	**Marla Benedek**	**Kobena Waters**
______________	______________	______________
Emily Green	**Yu Lun**	**Tiancheng Wang**
______________	______________	______________

Reviewed by: Dr. Jae K. Shim and Dr. Svetla Baykoucheva

Table of Contents

Abstract

Neuromuscular changes associated with aging increase the potential to fall and the potential to get injured from falling, which causes long term complications. Studies have shown that resistance training increases stability through improving muscular strength. This study compares the effects of whole-leg and individual-joint training on synergy and balance of both college age students and the elderly. We also hope to further the understanding of the neuromuscular system's response to resistance training. Using a matched-subject random assignment design, we will analyze the data between the two types of training over six weeks. The findings will help decrease the falling rates of the elderly and improve their quality of life.

Introduction

Everyone falls, no matter what age. However, muscular atrophy and skeletal degeneration due to age often results in frailty and frailty-related complications, causing injuries from falls to rank among the most significant reasons for geriatric hospitalization (American Geriatric Society, British Geriatrics Society and American Academy of Orthopaedic Surgeons Panel on Falls Prevention, 2001). The Centers for Disease Control (CDC) defines quality of life as an individual's perceived physical and mental health, promoted through the prevention and control of disease, injury and disability. Therefore, prevention and control of loss of balance, which would decrease incidence of injury and disability, would directly improve quality of life.

Prior research has shown that physical training in the form of specific exercises can strengthen muscles around joints, thereby greatly decreasing the possibility of malfunction and instability (Pijnappels, Reeves, Maganaris, and van Dieen, 2008). Moreover, study of various muscular systems, including that of the hand, has shown that muscular systems often exhibit interdependency, the firing of multiple analogous muscles in a motor system from a motor impulse to only one muscle. Further studies show that separate training of individual joints results in greater muscular control and minimizes interdependency.

Stability depends greatly on the ability to correct the error of moving one's center of balance, defined as one's center of gravity projected onto the ground, beyond one's base of stability, established by the feet and the area between the feet. In terms of the leg joints (hip, knee, and ankle), the fastest and most efficient way of correcting that error is the movement of the two non-malfunctioning joints in the opposite orientation from the error.

As such, whole-leg exercises, which reinforce interdependency, would amplify the error of a single joint, as the other joints would also fire in the direction of the error. Conversely, elimination of interdependency through individual-joint exercises, therefore, would allow for the other joints to fire independently of the erroneous joint and compensate for the error instead of amplifying it.

Considering that the vast majority of the increasingly large geriatric population regularly face the possibility, reality, and complications of falling and the fact that the majority of current physical therapy programs focus more on whole-leg exercises, research validating the higher value of individual-joint exercises and the development of an interventional therapy program using such exercises would be of great interest to the geriatric population.

In addition to having interventional value, individual-joint training, if begun early, would allow for prevention of muscular and neural degeneration and, thus, lack of balance. Since individual-joint training focuses on increasing muscular independence through neural adaptation, a universally observed human phenomenon, as much as it does on increasing muscular strength, any age group past childhood would benefit from its application.

So, this study will address the research question: how does the human neuromuscular system respond to individual-joint and whole-leg resistance training with regard to improving motor synergy* and muscular strength for balance maintenance and recovery? To do this, we will recruit subjects aged 18-24 from the University of Maryland, College Park campus as well as geriatric subjects aged 65 and older from retirement and elderly care facilities within and around the College Park, Maryland area.

These subjects will be match-paired for height, weight, gender, and age into two experimental groups: the whole-leg training (WLT) group, which will train with the leg press exercise, and the individual-joint training (IJT) group, which will train with back extension, knee extension, and ankle plantarflexion exercises. We hypothesize that individual-joint training will increase motor synergy more than whole-leg training, whole-leg training will increase muscular strength more than individual-joint training, both types of training will increase balance maintenance and recovery, and individual-joint training will increase balance maintenance and recovery more than whole-leg training.

Literature Review

According to the study published by American Geriatric Society (AGS), British Geriatric Society and the American Academy of Orthopaedic Surgeons Panel on Falls Prevention (2001), 35-40% of all community dwelling elderly adults aged 60 and older fall, and an even higher incidence of falls occurs in the aged 70 and older population. The same report in 2001 also established that 5% of these falls result in fractures, 5-10% of the elderly adult who fell received major injuries requiring medical attention, a causal relationship is established between the falls and 12% of all deaths within this population, and falling is the fifth highest cause of death among the elderly. The AGS et al study (2001) also accounts that 6% of all medical costs for the elderly were related to injuries obtained from falling and that recurrent falls usually result in admission of previously independent elderly persons to long-term care programs.

In 2002, Ferber, Osternig, Woollacott, Wasielewski and Lee, noted that two major factors were needed to effectively maintain balance: ability to manage a changing base of support and center of mass and ability to adjust quickly to changes in this equilibrium. Due to the necessity of these abilities, the increased likelihood of elderly to fall is caused in a large part by significant decrease in muscle strength and power due to muscular degeneration and neurological changes (Macaluso and De Vito, 2003). Muscular degeneration includes loss of muscle mass, known as sarcopenia, and loss of tension in muscle fibers and tendons. Neurological changes include decreasing activity of agonist muscles, the muscles that contract to cause a specific motion, and increasing activity of antagonist muscles, the muscles that relax as the agonist muscles contract to allow the same specific motion. In 2002, Ferber et al found a tradeoff between the hip and knee after forward perturbation: when one was experiencing a flexor moment, the other was experiencing an extensor moment, and vice versa. Additionally, Dieen, Pijnappels, and Bobbert (2005) described the hindrance of balance recovery by a delayed reaction of the recovery leg caused by neural degradation due to aging. As people age, the number of motor neurons in the spinal cord declines, resulting in a loss of some motor units and a rearrangement of others by a higher innervation ratio, resulting in less independent control of muscle groups (Enoka, 1997).

Prior research has shown that muscular exercise can address the problem of frailty and increase balance maintenance. In 2008, Pijnappels, et. al., found a direct correlation between strength training and increased balance. The elderly participants in the study did knee extensions, leg presses, and calf raises for two exercise sessions each week, which significantly increased both strength and balance. Also, Costello and Edelstein (2008) concluded from indepth analysis of literature pertaining to the incidence of falls among the elderly that an exercise program involving both exercises targeting balance and muscle strengthening, aerobic or endurance training will effectively reduce falls. Furthermore, a study conducted by Hartmann, Murer, De Bie and De Bruin in 2009 found that conventional strength, balance and gait training can significantly improve the lower extremity muscle power and functional abilities of elderly subjects. In addition, Silsupadol et al. (2009) found that dual-task training such as walking and counting simultaneously effectively improves gait speed and balance under dual-task conditions in elderly patients with balance impairment. Interestingly, Tomioka, et. al. found in a study in 2001 that there was significant difference between knee strength and hip-knee coordination; they studied the contribution of each to vertical jump and concluded that strength was not the only factor in maintaining balance.

It was not a surprise, then, that other research found that, during eight weeks of isotonic strength training, neural adjustments were the major contributor to strength. However, after 3-5 weeks, hypertrophy was the bigger contributor (Moritani & deVries, 1979). Along the same lines, Enoka (1997)found that older adults exhibited 40-300% strength increase over 8-12 weeks of strength training, with only 10-15% attributed to muscle mass increase and the remainder due to neural adaptation.

There are three main pieces of evidence supporting the theory that neural mechanisms play a major role in adaptations during physical activity. First of all, strength increases in the first few weeks of training prior to a significant increase in muscle mass; the cross-sectional areas of muscle fibers do not exhibit a significant increase until eight weeks into a training program (Enoka, 1997). Secondly, an untrained limb exhibits an increase in strength when its contralateral, or opposing, limb has been trained, and effect called “cross-education” (Farthing, Borowsky, Chilibeck, Binsted and Sarty, 2007). Finally, increase in muscle strength is task specific, as evinced by a study that showed an increase in isotonic muscle strength after twelve weeks of isotonic training, while the isometric strength of the same muscles showed no significant increase (Enoka, 1997).

However, though a plethora of evidence supports the notion of neuromuscular adaptability in strength increase, the mechanisms by which these adaptations occur is still unknown. Enoka (1997) acknowledges that the mechanism is likely tied to maximality, specificity, or the neural pattern to the muscle.

One neural phenomenon exhibited by many motor systems throughout the body, muscular interdependency, has been described and studied, most notably in the fingers of the hand where it is known as the enslaving phenomenon (Slobounov, Johnston, Chiang, and Ray, 2002). Muscular interdependency describes the phenomenon of a muscle group contracting when a neighboring or analogous muscle group contracts, such as the bending of the middle or pinky finger when the ring finger is bent, even if the conscious effort is to keep all but the ring finger straight (Shim, Hsu, Karol and Hurley, 2008).

As previously noted, neurological pathways can be adjusted through resistance training. Muscular interdependency is no different. Shim et al (2008) found that resistance training of one finger while the others were restrained caused a decrease in the interdependency between the fingers of that hand. In a more general study, Duchateau, Semmler and Enoka (2006). found that adaptations to reduce the coactivation of agonist and antagonist muscles during training are related to the ability of muscles to perform specific tasks by focusing motor command to the appropriate muscles. In other words, training adjusts the neural pathway to decrease the coactivation of agonist and antagonist muscles, increasing the strength of the agonist muscle in performing that specific movement.

Methodology

Subjects

In order to implement a matched-subject random assignment design, the subjects must be distributed evenly into two groups with similar gender ratios. We have been unable to find sample means and standard deviations in literature that we can use to calculate an approximately suitable sample size, so the team decided that, taking into account budgetary, retention, and temporal constraints, the sample size should be an even number between 26-30 (n=26-30), with half in each training group (Shim, JK, personal communication, September 29, 2009). Dr. Jae K. Shim suggested that sample size should include 8 subjects per group (n = 16) minimally (Shim, J.K. personal communication, October 6, 2009).

While we will mainly focus our research college-aged students, we will also look at geriatric subjects (above the age of 65) because they are the ones who will benefit the most from the research results. During the college-aged student trials, we will also be conducting separate trials from the elderly subjects with rolling recruitment. Ideally, the sample population size for the geriatric subjects would also be an even number between 26-30; in the case the sample size is low, the team will forgo statistical significance and turn to qualitative analysis instead.

The main demographic parameter for the subjects is that they are of college age (18-24 years). In order to eliminate height and weight as confounding variables, the team will determine the training protocol from and compare the end results of training proportionally to each subject's measured baseline, acquired during the first testing session. Another major constraint is the necessity for subjects to not engage in regular exercise, especially progressive resistance training (i.e. weight lifting), and intercollegiate athletics. Such significant extraneous exercise will confound data by introducing neural and muscular changes not induced by the experimental training; an increase in the cross-section area of the muscle can also contribute to an increase in strength, which is what the team is using to qualitatively measure the change in muscle stature (Reeves, Narici, and Maganaris, 2004). To quantify the activity level of our subjects, we will use the International Physical Activity Questionnaire (IPAQ) short form, which is available to the public at the IPAQ Research Committee website (Persch, Ugrinowitsch, Pereira and Rodacki, 2009). The subjects will be asked to answer a series of short questions and the responses scored according to the accompanying rubric in the IPAQ manual (IPAQ Research Committee, 2005)[1]. Additionally, since the project is testing neurological responses to muscular training, the subjects must be free of any disorders that could impair neurological or skeletal-muscular development, such as Dwarfism, Alzheimer's, and brain tumors, as they respond to training and testing modulesdifferently than healthy subjects (Hale, Miller, Barach, Skinner and Gray, 2009).

Due to the fact that we will work with human subjects, there are confounding variables that we cannot control absolutely. For example, we cannot monitorsubject intake of nutritional supplements, recreational drugs or alcohol. Nutritional supplements can increase muscle mass and energy level and drugs of any kind will affect subjects' physiological responses to training and testing, all of which would skew gathered data. For the elderly subjects, it is critical for the researchers to carefully screen their medications—some medications will have adverse side effects on balance and neurological responses. There is, however, no feasible and ethical method to limit subject intake of nutritional supplements or consumption of alcohol, recreational or

[1] Both the IPAQ manual and the scoring rubric are available online in various formats and languages at http://www.ipaq.ki.se/downloads.htm (IPAQ survey) and http://www.ipaq.ki.se/scoring.pdf (scoring rubric).

medical drugs. The team can minimize the effects of these potentially confounding variables through screening the initial pool of subjects to eliminate those who self-report drug and alcohol use; however, lack of subject honesty could skew results. We must also consider that some subjects may falsely report their information due to the monetary incentive; to counter this possible confounding variable, the team would not advertise the specific parameters of our subject requirement. Instead, we will only announce the most basic requirements such as age, gender, and being a member of University of Maryland, College Park community. We hope that by withholding information, we would be able to limit the subjects' desire to falsify information since they cannot predict what kind of subject we are looking for. To maintain subject confidentiality, each candidate would be assigned a subject number prior to the screening processand any volunteered information will only be associated with the subject number and used solely for screening and matching purposes. The researchers will follow strict confidentiality guidelines and keep all data gathered throughout the experiment private.

The population college students (ages 18-24) will be recruited from the University of Maryland, College Park campus. Initial recruitment will begin with freshman classes such as GEMS100, HONR100, and UNIV100. The researchers will then expand to include the remainder of the student population 18-24 years of age, with special attention toward North Campus students due to the proximity of the residence halls to the testing and training center located in the School of Public Health building. Additionally, we plan to advertise on various college listserves and both put up and hand out flyers as often as necessary. The listserves are directed to the entire campus and thus serve to announce our research project to the entire student population; while the researchers will advertise on the listserves, we will not take any more actions to influence which students respond to our advertisement. The researchers will also take care to randomly place the subjects into the whole-leg and individual-joint treatment group, only looking to match the subjects so that each pool has similar subjects in terms of gender, physical activity level, alcohol consumption level, and drug intake level.

Elderly subjects will be recruited from nearby long-term care facilities as well as through advertising among establishments frequented by independent elderly adults—such as grocery stores, local newspapers, and through word of mouth. The team will contact several long-term care facilities near the College Park campus and work closely with their professional staff to negotiate any transportation and safety concerns.

As many physical training experiments experience problems with subject retention, we will address this issue with proper subject compensation. Based on previous studies, approximately 50% of all subjects who start a self-monitored exercise program will drop out; although members of the team will monitor our exercise-training program, we still rely heavily on the subjects' continuous voluntarily participating (Dishman, 1991). We estimate that on average, each subject participates in the study for 12 hours over 6 weeks for a total compensation of $120 (at least $10 per training hour), which will be paid in a tiered distribution. The subject will receive compensation on each of the four testing days, in increasingincrements. For example, a subject will earn $5 at the initial test, $15 at the second test, $35 at the third test, and $65 at the final test. Additionally, an extra $5 reward will be offered to each subject for the introduction of a friend who qualifies for the study and commits to being a subject. In order to maximize retention, subjects will be allowed to miss one training session every two weeks of training, but those who do not reschedule will have their compensation for those two weeks reduced by one-sixth, with the reduction rounded down to the nearest dollar.

Materials and Equipment

We will be using surface electromyography (SEMG) to see what muscles are being used. We will also be able to determine to what extent the muscles are exerted (Robertson, Caldwell, Hamil, Kamen, and Whittlesey, 2004). A muscle becomes active when a signal travels from the central nervous system through a motor neuron, or motoneuron, to the muscle fibers. This message increases the permeability of the muscle fiber membrane to sodium ions, causing the ions to rush into the fiber, creating a net positive charge inside the cells. To retain neutrality, the membrane's permeability to potassium ions increases and the potassium floods out of the fiber. According to Robertson et al. (2004), the SEMG method measures the exchange of ions as a signal We will use the Noraxon TeleMyo 2400T Direct Transmission System to measure these data (Noraxon, 2009a). This system is wireless, minimizing issues of inference. The sensors, which are electrodes, are placed directly onto the skin. Data collected by the electrodes are sent directly to a belt receiver. Using the MyoResearch complementary computer software, the patterns and strength of membrane electrical potential are recorded as data and analyzed to demonstrate muscle function (Noraxon, 2009b). The SEMG will enable us to analyze frequency, amplitude, timing, ergonomics, and jump.

We will be using the VICON™ Motus 9.0 motion measurement system in our two dimensional analysis of joint motion during testing. The two-dimensional analysis will utilize one camera, which records at a frame rate of 100 Hz at 656 x 492 resolution (Vicon, 2009). The data from this camera can be synchronized with the data retrieved from the SEMG and force plate devices to allow performance of multidimensional analysis (Vicon, 2009). The system software is able to track the movement of reflective markers, which will be placed at the ankle, knee, and hip (Vicon, 2009). According to Griffiths (2006), digitizing software detects these reflections in the film at every frame, calculates the center of each marker, and records the point coordinates within each frame in sequential order in the form of a table or graph. Griffiths (2006) also notes that system calibration requires the use of a reference object of known size, which must be placed at approximately the same distance as the reflective markers will be from the camera. Griffiths (2006) suggests that displacement, velocity, acceleration, angular displacement, angular velocity, and angular acceleration at each joint will be computed from the data.

We will use a portable, quartz piezoelectric force plate manufactured by the Kistler Instrument Corporation to measure the ground reaction forces (GRFs) experienced by the subjects under testing conditions (Kistler, 2009). Griffiths (2006) mentions that piezoelectric technology measures the electrical signals acquired from a change in electrical potential between crystalline facets as they undergo small deformations; these signals are converted into force, acceleration, and pressure parameters (Kistler, 2009). According to Griffiths (2006), GRFs and the corresponding moment outputs are measured in three dimensions along the x, y, and z axis. Griffiths's (2006) work suggests that the plate can be used for stability analysis and measurements of force, power, and work among our subjects.

Training (Individual-joint)

Each participant is paired with a specific researcher who will individually train the participant for the duration of the trial. Individual-joint training sessions will be comprised of three different exercises: leg extension exercises that target the knees, back extension exercises that target the hips, and ankle plantarflexion exercises.

During the leg extension exercise, participants will sit on the lever leg extension machine with their backs supported by the seat of the machine and their shins resting against the padded lever from below. During each repetition of the exercise, the participants will slowly extend their knees, lifting the lever as they straighten their legs. After fully extending their legs, the participants will pause for a moment and then slowly bend their knees again, bringing the lever back to its original position. Griffing (2009a) clarifies that for safety and stability during the exercise, participants should take care to keep their back supported against the seat and grip the handles on each side of the machine. Sitting upright in the machine also ensures that the participant completes the exercise correctly and successfully using the target muscles.

Our second individual-joint exercise, the back extension, begins the same way as the leg extension exercises: the participants sit in a machine with their backs against the padded lever. However, in this exercise, the participants' feet are supported on an immovable platform and their hips rest against the back of the seat of the machine. From this position, the participants will lean backwards, extending their spines into an arch-shape, pause for a moment, and then return to the original position, completing one repetition. While this exercise is referred to as a "back extension" and does primarily target the back, we are interested in the muscles required for stabilization during this exercise. As Griffing (2009b) clarifies, the exercise does not only work the back but also the muscles used to complete the repetitions, namely the quadriceps, gluteus maximus, adductor magnus, and hamstrings, and hips.

For our final exercise for individual-joint training, we will conduct ankle isolation exercises. We plan to use the specific exercise suggested by Griffin (2009c): ankle plantarflexion for the gastrocnemius and the soleus muscles. During this exercise, the participants will have a bar strapped to the bottoms of their feet. A weight will hang from the end of the bar behind the ankle. Participants will sit on a raised surface, their feet not touching the ground. From that position, they will stretch out their legs, rotate their feet downward and point their toes toward the ground, pause, then bring their feet back up to the original level position to complete one repetition.

We will rotate the order of the exercises so that the fatigue inherent in the resistance training will temper the effect of each exercise equally. This measure will also serve to break up the routine and encourage active participation from the subjects.

In a regular individual-joint training session, the participants will begin by stretching with their trainer in preparation for the weight training. The trainer will then instruct the participants in the first exercise—for example, plantar flexion. Each participant will complete ten repetitions at 75% of the maximum amount of weight he or she can lift—in other words, the one repetition maximum. There will be two minutes of rest between each set of repetitions of the same exercise and five minutes of rest between sets of different exercises. Each of the three training exercises for the training session will follow this format. Although this training plan totals three exercises for participants engaging in individual-joint training and only one exercise for participants participating in whole-leg training, our mentor, Dr. Shim, has assured us that the different trainings are indeed equal and comparable because each joint is receiving as much training in the individual-joint training sessions as the whole-leg is receiving in whole-leg training sessions (personal interview, November 17, 2009).

Training (Whole-leg)

The whole-leg exercise we are using is the leg press. The leg press uses all three joints, the hip, the knee, and the ankle, to produce force to push a weight away and upwards. The exercise is performed on a machine in which the subjects lay on the pad and place their feet against the plate which is on a track with a 45° elevation. The subjects then push the plate by extending their legs to their full length without locking their knees (Yessis, 2002). The muscles used include the Gluteus Maximus, Quadriceps, Hamstrings, Adductor Magnus, Soleus, and

Gastrocnemius. During the pushing the subjects' muscles are contracting concentrically and during the recover they are resisting the weight as well so the muscles contract eccentrically (Griffing, 2009c). Each participant in the whole-leg group would complete 3 sets of 10 repetitions each training session at 75% of their one rep max. High amount of repetitions with low weight train muscles to be able to contract repeatedly for long periods of time, building endurance; while a low number of repetitions with a larger amount of weight increases muscle size much more increasing strength significantly (Milner, 2008). We are using 75% of the one rep max because this is the perfect amount of weight with the repetitions used to build both strength and endurance.

Experimental Procedure

After we have screened applicants for sedentary lifestyles and absence of confounding disorders, subjects selected for the study will attend the first testing session. The first testing session will set the baselines of synergy, power, and strength for each individual subject using measurement devices such as Noraxon TeleMyo 2400T DirectTransmission System, SEMG, VICON™ Motus 9.0 motion measurement system, piezoelectric force plate by Kistler Instrument Corporation, and EMG and subsequent testing sessions will follow the same protocol. Data from this first testing session will be used as a comparative baseline to determine the physiological changes associated with whole-leg and single-joint training. After initial testing, we will split the subjects into the two training groups and model the use of the training equipment specific to each respective group. Subjects will then be required to demonstrate proper understanding of equipment operation before participating in the determination of an accurate repetition maximum (RM) per subject per exercise. To obtain the RM, the trainer will ask the participant to perform one repetition of the exercise at moderate resistance, and then slowly increase resistance until the subject can no longer perform one repetition. The greatest resistance at which the subject can perform one repetition is, by definition, the RM for that exercise. All subjects will be trained throughout the study using 75% of this initial RM. (Shim, J.K., personal communication, October 13, 2009).

Training starts once we have obtained all the RMs for all subjects for each piece of exercise equipment they will use. Subjects in both the whole-leg training group and the single-joint training group will come to the exercise training facility in the School of Public Health building three times a week for approximately half an hour each time for a total of six weeks. The whole-leg training group will do three sets of ten on the leg press at each training session. The single-joint training group will perform leg extension, plantarflexion, and back extension in three sets of ten repetitions each. Subjects in both groups will rest two minutes between sets and five minutes between different exercises.

Testing will be conducted before training and after the second, fourth, and final weeks of training. If a subject misses a training session, we will try to reschedule. However, we will give subjects the flexibility of missing one training session every two weeks at the cost of one-sixth of their next compensation payment. (Shim, J.K., personal communication, October 13, 2009). Testing days cannot be missed. If missed, we must reschedule to obtain data for analysis. If we cannot obtain data at each testing day from a subject, that particular subject must be excluded from final data analysis. The experimental procedure for elderly subjects models after that of college aged students.

Data Analysis

The “uncontrolled manifold” or UCM method provides the methodological basis for which we are able to link variance in our elemental variables (i.e. joint angles) to the variance in body position and balance (Schöner & Scholz, 2007). Through the UCM method, we will quantify joint synergy in order to indicate the level of balance control. The degree of joint synergy can be quantified by the delta variance (DV) of joint angles, EMG readings, and torque of the joints over the time period of the testing procedure. These are our elemental variables (Shim, J.K., personal communication, December 1, 2009). Each subject has a unique whole body center of mass (WBCM), which will help construct the multidimensional space used to calculate DV. The WBCM is calculated by the following equations, $X_{WBCM} = \frac{\sum m_j x_j}{\sum m_j}$ and $Y_{WBCM} = \frac{\sum m_j y_j}{\sum m_j}$ where m_j is the mass of each segment and x_j and y_j represent the positions of the centers of mass of each segment as a coronal plane and transverse plane respectively. We will be using the midsagittal plane as the Z_{WBCM} because it divides the body symmetrically into left and right portions (Appendix B and C). Combining the X_{WBCM}, Y_{WBCM} and Z_{WBCM} will determine the point of the individual's WBCM (Griffiths, 2006). The UCM is the multidimensional space containing all of the possible coordinates of a variable of interest (i.e. all possible combinations of joint angles) that results in the same end-effector position (Schöner & Scholz, 2007). The end-effector position for our research is a position of body stability and balance; this is unique for each participant based on their WBCM. The elemental variables will be projected onto this multidimensional space to determine the level of good and bad variance. In short, good variance (V_{ucm}) is contained within this space, whereas bad variance (V_{ort}) is projected away from the space orthogonally (Appendix D). The DV is a unitless variable and is calculated by the formula DV = $\frac{\frac{V_{ucm}}{n_{D-1}} - V_{ort}}{\frac{V_{ucm} + V_{ort}}{n_D}}$ where n_D equals the number of dimensions. When the DV is greater than zero, the body is exhibiting synergy, which helps motor performance in stabilizing the WBCM inside the base of balance. When the DV equals zero there is no synergy. When the DV is less than zero, the body is exhibiting synergy, which destabilizes the WBCM outside the base of balance (Shim, J.K., personal communication, December 1, 2009). For our purposes, a positive and increasing DV would demonstrate increasing balance control in our subjects.

To analyze the variability within our subject groups we will compute the mean, median, variance, and standard deviation of the DV, V_{ucm}, and V_{ort}. We will compare these values between the whole leg exercise group and the individual joint exercise group (Graziano, 1997). This analysis will give us an overview of the difference between the two groups. Then we will perform more specific data analysis between the two training protocols by comparing the variability in our matched subjects using ANOVA (Graziano, 1997).

Benefits and Limitations

Considering the research question and purpose of this study, there are inherent benefits within the project design. Since the progress of each subject will be compared against his or her own baseline, established in the first testing session, the need for a separate control group is eliminated, as the two exercise groups will be compared using relative growth data from each group. Also, the absence of restrictions on height, weight, and gender as well as the inclusion of subjects from both ends of the age spectrum allows generalization to almost the entire population, allowing that many more people to apply and benefit from this training.

Conversely, the study also includes a few inherent drawbacks. We expect low recruitment and high dropout rates due to the time commitment of six weeks of three training sessions per week and testing every other week. Also, because the concept of motor synergy has not been explored very much at all, we must define both a sufficient sample size and a method of quantifying the variable. Also, because of the incentive offered, potential subjects that consume dietary supplements, alcohol, and recreational drugs will be biased to respond dishonestly in order to increase their chances of being included in the study.

Anticipated Results and Significance

We anticipate that both types of training, will increase balance: WLT through the increase of muscular strength and IJT through the increase of both muscular strength and motor synergy. As such, we expect to see WLT result in a greater increase in muscular strength, even though both types of training will increase muscular strength. However, we anticipate that IJT will greater increase balance maintenance and recovery.

Although the muscular benefits of resistance training have been and continue to be thoroughly investigated, much less research has explored the neurological changes that resistance training induces, and basically no research has sought and understanding of both how such training can adjust neurological responses and what benefits can be gained from the application of such training specifically to alter neurological responses. That is what this study seeks to find.

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INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRES

IPAQ: SHORT LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health-related physical activity.

Background on IPAQ

The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken in 12 countries (14 sites) across 6 continents during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages. IPAQ is suitable for use in regional, national and international monitoring and surveillance systems and for use in research projects and public health program planning and evaluation. International collaboration on IPAQ is on-going and an international prevalence study is under development.

Using IPAQ

Worldwide use of the IPAQ instruments for monitoring and research purposes is encouraged.

It is strongly recommended, to ensure data quality and comparability and to facilitate the development of an international database on health-related physical activity, that

- no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments,
- if additional questions on physical activity are needed they should follow the IPAQ items,
- translations are undertaken using the prescribed back translation methods (see website)
- new translated versions of IPAQ be made available to others via the web site to avoid duplication of effort and different versions in the same language,
- a copy of IPAQ data from representative samples at national, state or regional level be provided to the IPAQ data storage center for future collaborative use (with permission) by those who contribute.

More Information

Two scientific publications presenting the methods and the pooled results from the IPAQ reliability and validity study are due out in 2002.

More detailed information on the IPAQ process, the research methods used in the development of the IPAQ instruments, the use of IPAQ, the published papers and abstracts and the on-going international collaboration is available on the IPAQ web-site.

www.ipaq.ki.se

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

IPAQ: SHORT LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS

NOTE: EXAMPLES OF ACTIVITIES MAY BE REPLACED BY CULTURALLY RELEVANT EXAMPLES WITH THE SAME METS VALUES (SEE AINSWORTH *ET AL*., 2000).

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. This is part of a large study being conducted in many countries around the world. Your answers will help us to understand how active we are compared with people in other countries.

The questions are about the time you spent being physically active in the last 7 days. They include questions about activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Your answers are important.

Please answer each question even if you do not consider yourself to be an active person.

THANK YOU FOR PARTICIPATING.

In answering the following questions,

- **vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder that normal.

- **moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder that normal.

1a. During the last 7 days, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling,?

Think about *only* those physical activities that you did for at least 10 minutes at a time.

________ **days per week** ⇨

or

none

1b. How much time in total did you usually spend on one of those days doing vigorous physical activities*?*

_____ **hours** ______ **minutes**

2a. Again, think *only* about those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

________ **days per week** ⇨

or

none

2b. How much time in total did you usually spend on one of those days doing moderate physical activities*?*

_____ **hours** ______ **minutes**

3a. During the last 7 days, on how many days did you **walk** for at least 10 minutes at a time? This includes walking at work and at home, walking to travel from place to place, and any other walking that you did solely for recreation, sport, exercise or leisure.

________ **days per week** ⇨

or

none

3b. How much time in total did you usually spend walking on one of those days*?*

_____ **hours** ______ **minutes**

The last question is about the time you spent sitting on weekdays while at work, at home, while doing course work and during leisure time. This includes time spent sitting at a desk, visiting friends, reading traveling on a bus or sitting or lying down to watch television.

4. During the last 7 days, how much time in total did you usually spend *sitting* on a **week day?**

____ **hours** ______ **minutes**

This is the end of questionnaire, thank you for participating.

Appendix B—Body Plane

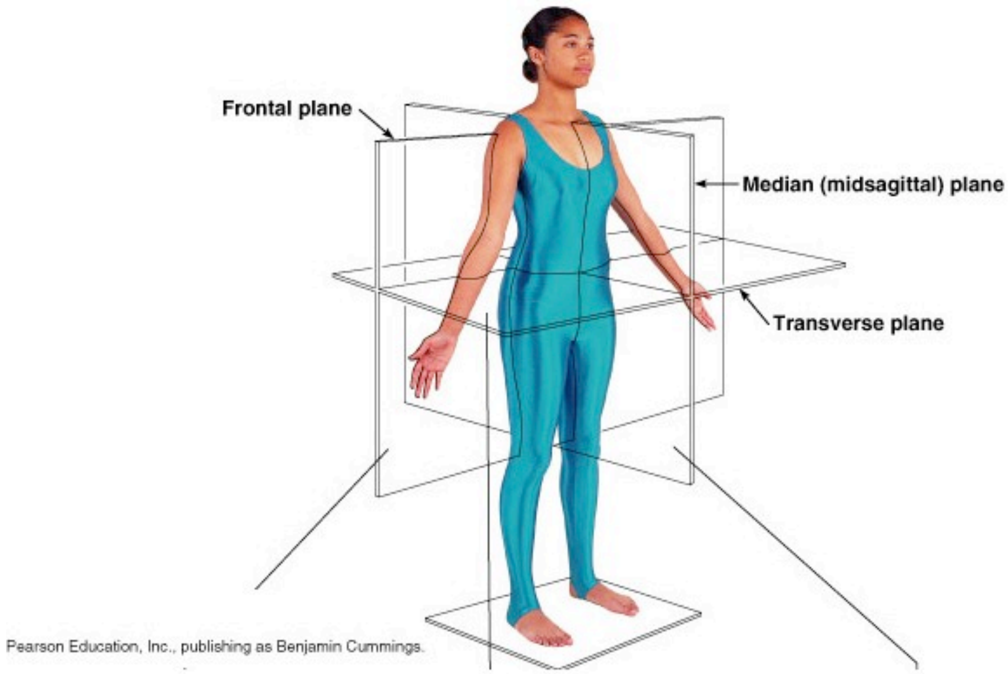

Figure B1

Appendix C—Glossary

Coronal (Frontal) Plane – a longitudinal (vertical) plane that divides the body into anterior (front) and posterior (back) parts (Glossary, 2007).

Transverse (Horizontal) Plane – a plane running from right to left, dividing the body into superior (upper) and inferior (lower) parts (Glossary, 2007).

Midsagittal (Median) Plane – a specific longitudinal (vertical) plane that divides the body into right and left portions and lies exactly in the midline (Glossary, 2007).

Appendix D—3D Graphs illustrating cloud of joint angle data points

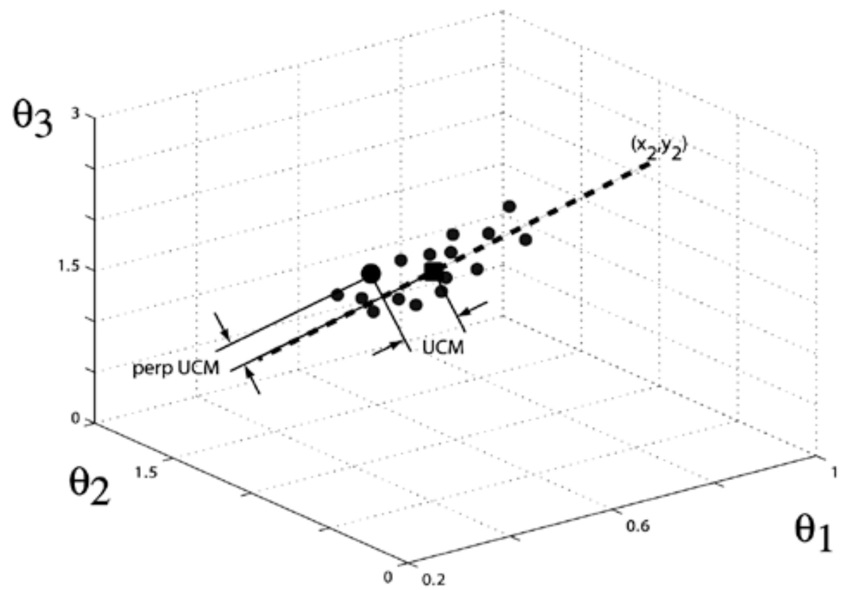

Figure D1

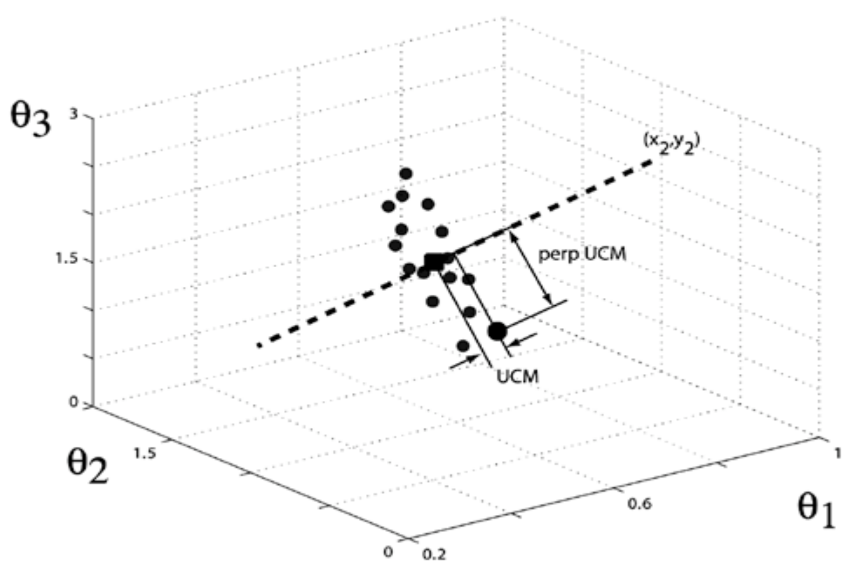

Figure D2

Appendix E--Timeline

	Winter 2010	Spring 2010	Summer 2010	Fall 2010	Winter 2011	Spring 2011	Summer 2011	Fall 2011	Winter 2012	Spring 2012	Summer 2012
Lit. Review	X	X	X	X	X	X	X	X			
Consult Experts	X	X	X	X	X	X	X	X	X	X	X
Recruitment of subjects		X	X	X	X	X	X	X			
Proposal/defense		X									
Training of subjects			X	X	X	X	X	X			
Obtain IRB	X										
Obtain funds		X	X	X	X	X	X				
Contact elderly communities		X	X	X	X	X	X				
Results and Data Analysis			X	X	X	X	X	X	X		
Outline Thesis				X	X	X	X				
Junior Colloquia				X							

Undergraduate Research day						X					
Draft/Thesis Critique							X	X			
Senior Orientation								X			
Complete Thesis								X	X		
Defend Thesis										X	
Publish results										X	X

Table A1 Team BALANCE's proposed timeline for completing our project on researching individual-joint and whole-leg training**.** This is a tentative schedule that we hope to refine as we become more knowledgeable about the research process and work out the specific requirements for our team's research.

Appendix F--Budget

Equipment for resistance training- Free, located in School of Public Health, and the ERC on campus

Lab Space- Provided by Dr. Shim

Use of Data analysis software- Provided by Dr. Shim

Use of Force plate, and EMG- Provided by Dr. Shim

Goal of 30 participants college-aged compensated $120 each- $3,600

Approximately 10 elderly subjects compensated $120 each- $1,200

Estimation of driving expenses for picking up elderly subjects- $500

Bottled water for training

(estimation of 40 participants x 3 training sessions a week x 6 weeks x 1 bottle of water~$0.35 each)

= $252

Estimated Total : $5,552

Our total is based on a minimum sample size, however we hope to be able to recruit, retain and manage as many subjects as our funding, and logistical constraints allow to improve the power of our findings.

Figure Captions

Figure B1 The planes of a human body from Marieb and Koehn (2004).

Figure D1. The cloud of joint angle data points represents good variance (V_{UCM}) from Schöner and Scholz (2007).

Figure D2. The cloud of joint angle data points represents bad variance (V_{ort}) from Schöner and Scholz (2007).