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Musculoskeletal injuries are common among military recruits: incidence rates of 20%-90% have been reported. Of these, as many as 87% are due to overuse. This project aims to predict individuals' susceptibility to muscle overuse injury based on their pattern of weakness and to develop ways of preventing and treating these overuse injuries. The hypothesis is that focal weakness predisposes to overuse syndromes (i.e. pain and inflammation of soft tissues) related to the weakened muscles and/or to those used in compensatory movement strategies. The muscle weakness experienced by many individuals with Post-Polio Syndrome (PPS) results in a pattern of accelerated overuse. This puts the PPS population in a unique position to serve as an accelerated model for the same weakness--overuse--injury cycle experienced by military recruits and occupational athletes. Muscle strength, range of motion, and symptomatology data are being collected on approximately 300 PPS subjects and 300 able-bodied subjects. Early results support the a priori predictions.

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Mary Ann Ruccimo 1-28-97

PI - Signature Date

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INTRODUCTION

Although there have been numerous studies dealing with muscle physiology, tissue response to injury, kinesiology (muscle use), kinematics (joint motion), and kinetics (force application), most of these studies have remained laboratory-based. Generally, this knowledge has not been applied to everyday clinical situations, occupational demands, or military training protocols. Efforts to apply laboratory technology and knowledge in this field of research have been directed toward a very small group: the elite professional or Olympic athlete. Minimal efforts have been undertaken to address the needs and demands placed on "occupational athletes", "military athletes", or "Activities of Daily Living (ADL) athletes".

The ADL athlete is perhaps the least appreciated and understood. The strength and energy demands of common daily activities are greater than realized. They necessitate great endurance as well as durability and strength. The demands of specific common activities, such as rising from a chair, are largely unknown. Likewise, many studies have documented the high rate of injuries suffered by military recruits during initial weeks of training, which may push unconditioned muscles to or beyond limits of endurance.[1,2,3,4] Even less understood are the compensatory mechanisms used when there is muscle weakness or pain.

The relationship between muscle weakness, overuse, and injury, is one that has received much clinical attention. Muscle weakness can be found in an unconditioned individual, after injury, or after illness, and may arise for a variety of reasons:

- Chronic weakness in a given muscle group may result from a neurologic disease (e.g. polio) or an extremity injury. For example, there is evidence that muscle atrophy, weakness, and abnormal motor patterns may persist at least one to five years after an injury requiring immobilization[5], may affect distant, uninjured muscle groups[6], and may not resolve without conscious retraining.[7]

• Transient weakness results directly from a fatiguing task or pain-limitation on full muscle recruitment.[8] A pitcher in a ball game for a full nine innings would suffer transient weakness in his throwing arm.[9]

• Under certain conditions requiring supranormal tasks demands, a muscle or group of muscles of normal strength may display relative weakness. An unconditioned individual required to run ten miles, or a non-weight lifter trying to lift 500 lbs. would fall into this category.

Obviously, these various etiologies produce weakness of different kinds, but each may lead to overuse of muscles to carry out certain tasks. The overuse can occur directly: weak muscle themselves need to work harder to maintain a certain force, thus becoming overused. The overuse may also be incurred indirectly, in alternate muscles that are recruited to compensate for the weak ones. Moreover, the relationship between focal weakness, focal overuse, and injury is both a cyclical and a reciprocal one, weakness producing overuse, overuse causing further weakness, and both predisposing to injury. (See Figure 1 in Appendix I) The injury can occur in the muscles themselves or in joint, capsule, or bone, since overused muscles are less capable of protecting these structures.[1,2]

People with Post-Polio Syndrome (PPS) enter the cycle with chronically weak muscles. Military recruits most probably enter either with overuse or transient or relative weakness, induced by an unconditioned individual starting a rigorous training regimen. ADL athletes may enter at any point, two examples being surgery-induced weakness or repetitive demands leading to overuse (as in carpal tunnel syndrome by data entry personnel).

Though each of these populations enter the cycle at different points and at different levels of weakness, once in the cycle they are all prone to injury via the same biomechanical mechanisms. For this reason, PPS provides an excellent model for the study of all overuse disorders. The muscle weakness experienced in PPS causes accelerated overuse, allowing the overuse to be readily observed in a small population over a short period of time. Over time polio survivors become masterful in a wide variety of compensatory techniques. They, therefore, also provide an excellent model to study the nature of compensatory muscle use and the induction of secondary injuries.

Muscle Overuse and Trauma in Military Recruits and ADL Athletes

Musculoskeletal injuries are alarmingly common in military recruits: incidence rates of 20-90% have been reported. [1,3,4,10,11,12,13] Of these, as many as 87% are due to overuse.[10] The bulk of these overuse injuries occur in the initial weeks of training, when rigorous physical demands represent an extreme increase in activity level for almost all recruits. As in PPS, most injuries are in the lower limbs. Musculoskeletal disorders are increasing in the military and, by 1991, accounted for 67% of medical discharges, incurring a cost to the Air Force of at least $2.7 million over five years. [3] They may also lead to diminished combat performance, as evidenced by evacuation hospital findings in Operation Desert Storm and Operation Uphold Democracy. [14,15]

A variety of factors in military training programs have been implicated in these injuries, including: exercising when fatigued, length of marches, training surface, arrangement of platoons (allowing shortest recruits to set stride length by placing them in front may reduce injury), stamping of feet on asphalt when coming to attention, design and fit of boots, carrying heavy weights overhead, and training techniques, including increasing the intensity, duration, or frequency of training too rapidly. [1,16] Thus, simple adjustments to training regimens could produce significant improvements in injury rates. [2] Additional factors that have been implicated in military overuse injuries include: prior exercise regimen and level of physical conditioning, running history, emotional status, and environmental factors, such as the height of obstacles on a training course.[3] More research needs to be done, however, to determine the extent and relative importance of each predisposing factor.

Among civilians, occupational activities and recreational exercise are the most common sources of muscle overuse and injury. According to Renstrom, the yearly incidence of running injuries is between 37% and 56%. Increases in activity intensity, injury history, muscle weakness, and idiopathic biomechanics have been implicated in the etiology of athletic injuries. [17]

Prevalence of Subclinical Focal Weakness in Military Recruits and ADL Athletes

Though not much is known about the incidence of subclinical focal weakness in normal individuals, significant paresis can exist in individuals who are diagnosed as "normal" by manual muscle testing, and who function and feel normal in active daily life.[18] Moreover, the population from which the military secures its recruits, i.e. active, athletic young adults, are the same individuals most likely to have suffered some kind of injury due to athletics. Such injuries have a "subclinical" effect on muscle operation long after full recovery is assumed. [5,6]

Transient or relative weakness may be very common in this population given the high intensity nature of training. It should be emphasized that in such a healthy, fit population biomechanical compensation can allow an individual to continue activity at a normal level. In this situation he or she may be overusing muscles to compensate for an undetected subclinical focal injury or weakness and thus, do permanent muscular damage.

Overt and Subclinical Weakness Produced by Polio

There are 1.5 million people in America who have residual paralysis from poliomyelitis. At present approximately 40% of these people have experienced a significant decline in their ability to function in recent years. This functional decline has been called Post-Polio Syndrome (PPS). PPS is usually diagnosed 30-40 years after the initial polio infection. All individuals with prior polio are at risk for developing PPS unless they receive preventative treatment.

PPS is characterized by a number of symptoms, including increasing muscle weakness, muscle and joint pain, incapacitating fatigue, and depression.[19,20,21] The loss of muscle strength can be perceived as sudden and severe. Additional symptoms include intolerance to cold, muscle atrophy, fasciculation, and sleep disorders.[19,21]

The major cause of PPS is thought to be the chronic overuse of muscles which were weakened by polio. In one study of PPS patients, polio-affected muscles were found to have strength values less than half those of healthy controls, mean fiber areas twice those of healthy controls, and low oxidative enzyme activity.[22]

Strength and endurance tests have revealed PPS patients to have significant deficits in neuromuscular function: in one study, PPS subjects had only 54% of normal strength and 51% of normal work capacity.[19] Another experiment, which evaluated the gait cycle of PPS patients, found that 85% of the subjects displayed excessive activity in at least two muscles; despite this increased effort level, subjects' mean free gait velocity was significantly lower than normal.[20] Thus, in a walking task, PPS patients need to overexert muscles even to achieve a subnormal result. These results were obtained even in patients classified as "strong" and who earned manual muscle testing grades of "good" and "normal".

Furthermore, it has been shown that PPS individuals needing to use a much higher portion of maximal effort than normals to carry out a given task suffer significantly diminished endurance capacities and extended recovery time.[19]

Overuse Injuries in PPS

Over time, PPS patients become adept at compensating for this well-documented weakness.[20,23] The result is overuse and trauma to compensating muscles as well as those weakened by the initial polio infection. Moreover, the problem is exacerbated by the fact that patients seem willing to accept chronic pain as "the price" of having had polio, and many suffer for years, often denying their pain and weakness, and incurring further damage to muscle tissue, before requesting clinical help. The most common overuse injuries observed in this population at the Einstein Post-Polio clinic are shown in Figure 2 (in Appendix I).

Post-Polio Syndrome as a Model for Muscle Overuse and Trauma in Military Recruits and ADL Athletes

The extensive muscle weakness experienced by most individuals with PPS results in a pattern of accelerated overuse and, often, subsequent trauma. This puts the PPS population in a unique position to serve as an accelerated model for the same weakness--overuse--injury cycle experienced in normal populations, such as military recruits and ADL athletes.

An important point to note is that although the muscle weakness of the polio survivor is more pronounced than that noted in the general population, polio is not a primary muscle disease, so normal muscle physiology, sensation, and motor control are preserved.[20] It is thus a "pure" model for study of the effects of muscle weakness on the remainder of the musculoskeletal system, namely muscle, tendons, ligaments, and joints.

Thus, this well-defined PPS population is enabling AEHN to study the effects of muscle weakness and overuse more efficiently. The hypotheses being tested by the proposed studies should help to elucidate: the relationship between overuse and trauma; the effectiveness of various interventions in breaking this cycle of muscle abuse, and the potential ability to predict what specific injuries may result from specific weaknesses.

In summary, it is hypothesized that a predictive model of overuse symptoms must make use of at least three sources of information: patterns of localized muscle weakness; patterns of biomechanical compensation for existing weakness; and the nature of the biomechanical demands of particular tasks and activities.

METHOD & PROCEDURES

Hypothesis A: Muscle Weakness is Associated with Overuse by Both Direct and Compensatory Mechanisms, Resulting Ultimately in Clinical Symptoms.

Study #1: Cross-Sectional Study of the Relationship Between Patterns of Weakness and Patterns of Overuse Symptoms in Post-Polio Survivors

Rationale:

If it is the case that specific muscle weakness leads to overuse both of the weakened muscle(s) and of those used to compensate for its weakness, then one would predict that identification and treatment of localized muscle weakness could lower the risk of development of overuse symptoms. The first step along this path was to establish a systematic relationship between the presence and location of weakness and the prevalence and location of overuse symptoms.

Objectives:

1) to determine the pattern of muscle weakness seen in the trunk and extremities in PPS;
2) to determine the prevalence of soft tissue overuse disorders and injuries
3) to determine the relationship of muscle weakness to the specific observed overuse injuries, both direct and compensatory.

Subjects:

The goal is to recruit 300 polio survivors (150 male and 150 female) from the Albert Einstein Post Polio Clinic and the community at large (the surrounding four-state area: Pennsylvania, New Jersey, Delaware, and southern New York) to participate in this study. Currently, 105 polio survivors (36 male and 69 female) have either been enrolled or have scheduled an appointment at the Research Clinic. The criteria used in subject selection are as follows:

1) history of polio

2) no major disability unrelated to polio that could cause weakness or overuse problems (e.g. stroke, amputation, diabetes, inflammatory arthritis, peripheral neuropathy, muscular dystrophy, congenital malformation)

3) no serious illness such as heart or lung disease which would make it unsafe for the subject to exert him/herself in a strength test (i.e. severe emphysema, poorly controlled asthma, resting angina, recent heart attack, recent treatment for an uncontrolled heart problem)

4) no fractures within the past six months

Consent:

Informed consent to participate in the study has been and will be obtained from all subjects. No significant risk of participation in the study is anticipated and no adverse events have occurred to date. The study has the approval of the Institutional Review Board.

Methods:

Each subject is seen in the Research Clinic for an initial visit, following a standard procedure. To ensure diagnostic reliability and minimize bias throughout the study, one clinician evaluates strength and another symptomatology, each blinded from the other's evaluation. A nurse practitioner conducts a brief clinical interview to review a standardized history which includes an inventory of activities that may predispose to overuse symptoms (See Appendix II). The subject's height (cm) and weight (kg) are measured using a standard scale. The nurse then conducts a symptomatology evaluation.

For the symptomatology evaluation, the subject starts out in a sitting position. The nurse starts at the shoulder and using palpation in combination with tests for specific overuse symptoms, looks for areas of pain or tendinitis. She examines each of the major joints using tests which are specific for each particular joint. These tests are listed in Appendix III. The right side of the body is tested first, followed by the left side. A positive or negative response is recorded for each test. If the response is positive, the subject is asked to rate their pain on a visual analog scale (VAS). This scale consists of a 100 mm vertical line with the words "No Pain" at the bottom end and "Pain as bad as it could be" at the top end. The subject puts a line on the scale corresponding to their feeling of pain or discomfort. They are also asked to identify the estimated date of onset of the pain and whether there are any specific activities which seem to aggravate their symptoms.

Once the symptomatology evaluation is completed, the nurse measures the true leg length and the thigh and calf circumference for both legs. This is followed by the range of motion evaluation for all major joints. A minimum of two trials are completed for each joint. During this examination, if the nurse determines that there is significant pain which would interfere with accurate strength measurements based on the VAS rating, she gives an injection of local anesthetic. She also has the option of requesting a radiograph when necessary for a diagnosis.

Next, a physical therapist or physical therapy assistant performs a manual strength examination using a hand-held dynamometer (Empi Microfet2, St. Paul, MN). All muscle groups are tested in a gravity-eliminated posture. The postures, placement of the dynamometer, and stabilization points are standardized (Appendix III). The verbal encouragement used for each test has also been standardized. For each test, the subject pushes against the padded dynamometer force plate which the physical therapist is holding stationary. This type of testing is called make testing. For each test, the subject is asked to slowly build to a maximal force and then hold this maximal effort for 4-5 seconds. There is a minimum of two trials for each muscle group. The maximum number of trials for a single muscle group is four. The digital hand-held dynamometer measures the peak force. This dynamometer has a range of 0 to 100 lbs. The accuracy of the dynamometers used in this study is checked periodically by vertically loading certified weights on their end pieces.

Once the dynamometer testing is completed, the physical therapist performs manual muscle testing using a standardized protocol on selected muscle groups since eligibility for the treatment studies depends on manual muscle strength levels. These muscle groups are the shoulder flexors and abductors, knee flexors and extensors, hip extensors and abductors, and ankle plantar flexors. Each test is done in a gravity-resistant posture and the Lovett grading system is used. If the grade is equal to or greater than 3 it is specified. Otherwise a muscle grade of <3 is recorded.

Additionally, approximately 40 subjects, each with upper extremity and lower extremity strength of greater than grade 3 will undergo some additional strength testing as a reliability check for the dynamometer and to determine inter-rater reliability.

Study #2: Longitudinal Study of the Development of New Overuse Symptoms in Post-Polio Survivors

Rationale:

From the cross-sectional study, it will not be possible to determine with certainty whether weakness leads to overuse symptoms, or whether overuse symptoms lead to weakness (through reduced activity of the affected limb). In order to clarify the direction of causation, strength data gathered at one clinic visit will be used to predict onset of new overuse symptoms at subsequent visits.

Objectives:

1) to determine the incidence of new soft tissue muscle overuse problems;

2) to determine the continued prevalence of those soft tissue overuse disorders detected in the initial screening; and

3) to clarify the causal sequence of the weakness--overuse--injury cycle.

Subjects:

The full cohort of 300 PPS subjects as described for Study #1. Informed consent will be obtained for all subjects.

Methods:

The subjects undergo a standard Research Clinic evaluation, as described in Study #1, four times at approximately 3-4 month intervals.

Hypothesis B: Specific Patterns of Localized Muscle Weakness Lead to Predictable Patterns of Muscle Substitution

Study #3: Patterns of Muscle Substitution Used to Compensate for Focal Weakness in Survivors of Polio and Individuals with Recent Musculoskeletal Surgery

Rationale:

Since many of the overuse symptoms in PPS occur in strong muscles used to compensate for weak ones, it is necessary to understand the biomechanical strategies used in compensation in order to predict fully the location of overuse symptoms. The study of two common tasks in the presence of localized weakness may thus clarify the patterns of compensation used.

Objectives:

1) to determine the compensatory substitution patterns for hip and knee weakness;:

2) to determine the biomechanical characteristics that will predict overuse sites.

Subjects:

From the Research Clinic cohort, 20 subjects will be selected for participation in this study: 10 with predominant unilateral weakness of the hip extensors and 10 with predominant unilateral weakness of the knee extensors. Twenty control subjects will be recruited from the orthopedic practices of AEMC: 10 with recent unilateral hip surgery and 10 with recent unilateral knee surgery. Thus, comparison groups with weakness in the same muscle groups from different etiologies will be identified. The specific criteria used in subject selection are as follows:

1) history of polio with either unilateral weakness of hip extensors or knee extensors (minimum of one MMT grade difference between sides). Potential subjects are identified using the MMT results from study #1.

OR

2) unilateral hip or knee surgery within the past six months

3) no major disabilities unrelated to their polio or recent surgery that could affect the pattern of muscle use during the research tasks

e.g. acute back pain, peripheral neuropathy, diabetes, amputation, stroke, cancer, inflammatory arthritis, muscular dystrophy

4) subjects must be able to stand up from a chair safely

Method:

Surgery patients will undergo a range of motion and muscle strength evaluation following the same protocol as for study #1. Subjects will be issued the standard precautions: not to overexert prior to the session, not to use creme or lotion on legs/arms, to bring shorts and a t-shirt or half-sleeve shirt. Subjects will be familiarized with the protocol and implications. Informed consent and permission to videotape will be obtained. Anthropometric parameters of both lower and upper extremities will be measured using calipers and measuring tape.

The skin will be cleaned and abraded with prep pads. Electrodes will be placed over the following muscles on both sides: tibialis anterior, soleus, vastus lateralis, rectus femoris, long head of biceps femoris, gluteus maximus, triceps, anterior aspect of the deltoid, and posterior aspect of the deltoid.

Selspot kinematic markers (LEDs) will also be placed in a standard configuration for bilateral lower extremity measurement. A video record will also be used to correlate quantitative differences in the pattern of motion. Twenty-four markers will be used. Full body marker placement will be as follows: a foot wand containing two LEDs, the base of which is positioned over the second metatarsal space of the foot. A marker will be placed on the lateral malleolus, a wand on the midspan of the lateral aspect of the tibia, a marker on the estimate of the anatomical knee center, a wand on the midspan of the lateral aspect of the femur, a marker on the trochanter, and wands will be placed on the left and right ASIS, and one midway between the left and right PSIS in the area of the second sacral space. For the upper extremity, a trunk, forearm, and upper arm marker coordinate system will be used. Data will be sampled at 50 Hz. for kinematics and at 500 Hz. for EMG.

The subject will perform a sit-stand task under three different sets of conditions. These conditions are as follows:

1) Hip flexion angle equal to 90 degrees, chair has no arms

2) Hip flexion angle equal to 90 degrees, chair has arms

3) Hip flexion angle equal to 70 degrees, chair has arms

The order in which these tests are performed will be randomized. Each subject will be encouraged to accomplish the task at their own pace. They will be instructed to place one foot on each force plate. Subjects will be asked not to twist excessively if possible in order to avoid compromising the force plate data. In condition (a), they will be told not to place their hands on the chair seat if they can perform the STS without them. If, having tried 3 times, the subjects are incapable of successful STS, they will be allowed to place their hands on the chair seat to assist them. In conditions (b) and (c), they will be asked to place their hands on the arm rests prior to beginnning the STS manuever. Subjects will be allowed to practice the STS manuever for each test condion. When they feel comfortable with the task, the experimenter will ask them to place their hands and feet in the position they will use to perform the task. These positions will be marked in order to keep hand and foot placement consistent between trials. Footswitches affixed to the seat will be used to determine lift-off from the chair. The arms of the chair will be instrumented with triaxial load cells in order to measure the forces placed upon them as the subject performs the STS.

Subjects will be given time to rest, as needed, between trials and conditions. In each condition, the subject will perform the sit-to-stand (STS) maneuver 4 to 6 times.

<u>Hypothesis C: The Greater the Degree of Localized Muscle Weakness, the Less Cumulative Intensity of Activity is Required to Produce Overuse Symptoms</u>

Study #4: Interaction Between Age and Severity of Weakness in Determining the Onset of Overuse Symptoms in Post-Polio Survivors

Rationale:

Overuse syndromes can occur abruptly, based on sudden maximal exertion. More commonly, however, they occur over time as overused structures gradually succumb to repetitive forces. Thus, among post-polio survivors, the prevalence of overuse symptoms should increase with age and the age of onset should be inversely related to the severity of weakness.

Objectives:

1) to determine if patients will greater weakness develop overuse injuries at a younger age

Subjects:

The full cohort of 300 PPS subjects as described for study #1.

Method:

This study rests on data gathered under the protocols of studies #1 and #2. Specifically, the strength, activity, and overuse symptom data from the first Research Clinic visit will be reanalyzed focusing on the effect of age.

Study #5: Development of Age-Related Norms for Changes in Strength and Prevalence of Subclinical Weakness Among Able-Bodied Individuals

Rationale:

In order to expand the PPS model of overuse syndromes to the able-bodied military and civilian populations, it is necessary to know the changes that occur in strength over the lifespan, and prevalence of subclinical focal weakness in the population at various ages. This will allow estimation of the susceptibility to overuse of individuals at different ages, and will set normative strength ranges in that context.

Objectives:

1) to determine a "normal" curve for changes in strength and the changing prevalence of subclinical weakness with age, which may enable identification of individuals at risk for overuse injury at a young age (e.g. military recruits);
2) to determine how much variability in strength there is in the population at large at any given age.

Subjects:

300 currently asymptomatic able-bodied individuals (150 males, 150 females) balanced across the age range 18-80 to be recruited from the community at large. This age range has been broken down into six smaller groups as listed below. A minimum of 25 males and 25 females in

each group will be tested. The broad range is used to allow normative estimates relevant to military and civilian workers, while also allowing comparisons to PPS patients, most of whom are middle aged or older. Currently, 98 able-bodied individuals have either been tested or are scheduled for an appointment.

GROUP	AGE RANGE
1	18-24
2	25-34
3	35-44
4	45-54
5	55- 64
6	65+

The criteria used in subject selection for this study are as follows:

1) no known history of polio or other diseases that might cause muscle weakness e.g. stroke, amputation, diabetes, peripheral neuropathy, inflammatory arthritis, muscular dystrophy
2) no unstable angina (chest pain due to heart disease that is not controlled by medicine)
3) no history of uncontrolled heart failure (heart failure that is not adequately controlled with medicine)
4) no severe breathing problems which require supplemental oxygen and could make it unsafe for subject to exert him/herself in a strength test.

Method:

Each subject is seen once for a standard strength examination using the hand-held dynamometer (see study #1) and a brief screening interview for history of extremity injuries.

<u>Hypothesis D: Interventions that Affect the Pattern of Muscle Use When There is Localized Muscle Weakness Can Reduce the Incidence and Prevalence of Overuse Disorders</u>

Study #6: A Comparison of Exercise and Lifestyle Modification, Alone, and In Combination, on the Resolution of Overuse Symptoms in a Post-Polio Population

Rationale:

If it is the case that focal weakness predisposes to overuse syndromes, then resolution of those syndromes should be facilitated by either strengthening the relevant muscle groups or altering the behavioral patterns leading to overuse.

Objectives:

1) to determine the efficacy of strengthening exercises and/or lifestyle modification on resolution of muscle overuse symptoms and prevention of new overuse symptoms.

Subjects:

A subset of 90 patients enrolled in the longitudinal study (#2), who have weakness of relevant muscle groups as well as symptoms of overuse believed to be related to the areas of weakness will be recruited into this study. To be eligible, the strength in their affected muscles must be grade 3 or better to allow effective strengthening.

Using our prediction models (Appendix IV), we identified three possible scenarios for subject selection. Each scenario specifies one or more muscle groups which we will be focusing on and the corresponding overuse symptoms. For scenario one, we will be looking at weakness in the hip and knee extensors. According to our model, people with weakness in these muscles will tend to use their shoulder muscles more in order to compensate (especially when rising from a seated position). Therefore, we would expect to see an increased number of overuse symptoms in the shoulder. For scenario two, we will be focusing on the ankle plantar flexor . People with weak calf muscles will tend to use their quadriceps or knee muscles more to compensate. Therefore, we would expect to see overuse symptoms in the knee. Finally, the third scenario focuses on the hip abductor. People with weak hip abductors are prone to developing hip tendinitis. Subjects who fall under any one of these scenarios will qualify for this study.

Method:

The subjects will be randomly assigned to three treatment groups of 30 each. Group 1 will be placed on a modified exercise program to increase strength of the specific muscle groups believed to contribute to their overuse symptoms. Group 2 will be carefully instructed in lifestyle modification to avoid overuse related to the areas of specific weakness. Group 3 will receive both treatment interventions. Subjects will be identified in the Research Clinic and enrolled following informed consent. At their initial visit after randomization, each subject will complete a visual analog scale of symptom severity and activity interview and receive a single local steroid injection if appropriate and a prescription for 10 days of acetaminaphen. Depending on their assigned treatment group, they will be instructed in a home strengthening program, a lifestyle modification program, or both. Although the specific exercises and lifestyle modifications will be individually tailored, the principles of prescription will be standardized across subjects. Instruction will combine an eductional videotape, individual consultation with a physical therapist, and printed material to take home.

Patients will be seen in the Research Clinic on a monthly basis for repeat strength assessment of relevant muscle groups, symptom assessment, an interview regarding compliance with the prescribed regimen, and a "booster" educational session. If there is inadequate resolution of symptoms by the third follow-up visit, the patient will be referred to the Open Clinic for further treatment outside the protocol. Documentation of non-protocol treatment and the results will be recorded in the database.

Study #7: Efficacy of Othotic Intervention in Altering Patterns of Muscle Use and in Relieving Symptoms of Plantar Fasciitis in Patients with and without Post-Polio Syndrome

Rationale:

Plantar fasciitis is common to both PPS patients and military recruits and, in many instances is believed to result from biomechanical factors. An orthosis which alters the pattern of muscle use in the lower extremity should, therefore, hasten resolution of symptoms in both groups. Although ankle-foot orthoses (AFOs) can alter forces and muscle activity in PPS patients with significant muscle weakness, molded shoe inserts, which could be used feasibly in the military or civilian populations, can have a similar effect in individuals with milder weakness and symptoms.

Objectives:

1) to determine the effect of short leg braces or shoe inserts on the pattern of muscle use in subjects with plantar fasciitis and on resolution of symptoms.

2) to determine if the orthotically-induced change in muscle use is predictive of resolution of overuse symptoms over a one-month period.

Subjects:

20 PPS subjects with plantar fasciitis recruited from the longitudinal study (#2); 20 subjects with plantar fasciitis recruited from the orthopedic practices of AEMC. The criteria for subject selection are as follows:

1) has been diagnosed with heel spur or plantar fasciitis

2) does not already wear a leg brace or shoe insert or have a foot that lacks feeling

3) no major disability which might affect how the subject uses his/her muscles

   e.g. stroke, amputation, diabetes, peripheral neuropathy, inflammatory arthritis, muscular dystrophy

4) must be able to walk unassisted.

Method:

Each subject will require four visits to the research clinic. At the first visit, a mold will be taken for a custom orthosis (shoe insert for controls; AFO for PPS patients) and severity of symptoms of plantar fasciitis will be rated on a visual analog scale. At the second visit, the orthosis will be fitted and the subject will wear it for 5 days to become accustomed to it. The subject will then return for a gait evaluation with and without the orthosis in random order. The gait evaluation will consist of kinetic, kinematic, and dynamic electromyographic data of 10 leg muscles. The subject will then continue to wear the orthosis and return in 1 month for a re-evaluation of symptoms on a visual analog scale. Subjects with residual symptoms will be referred to the Open Clinic.

RESULTS AND DISCUSSION

(GENERAL PROGRESS)

- Due to difficulty in recruiting a project director, the investigators requested and received a no cost six-month extension which moved the effective start date from January 1, 1996 to July 1, 1996.

- An extensive literature search was performed on activity questionnaires. The general features involved included type of administration (self-administered vs. interview), time frame covered (usual activity vs. recall of specific days), type of activities (occupational vs. leisure vs. home), and population (males vs. females, age range). For this relatively large-scale project, we decided that a questionnaire which is brief and self-administered would be the most practical in terms of both time and cost to the investigators and in terms of time for the subjects. We needed a questionnaire which would assess occupational, leisure and home activities since the subject population would range from young, working people to older retired or even disabled people.

This wide variation in the subject population for this project complicated the search for an appropriate activity assessment tool. We had to consider the variation in age, sex, and racial makeup of our various subject populations. Most of the available activity assessment questionnaires have been designed for white, middle-aged male populations. Very little information is available on the appropriateness of various questionnaires for assessing activity levels in females, nonwhites, and elderly. In addition, the applicability of these questionnaires for sedentary, able-bodied and disabled individuals is questionable because most of the research to date has involved relatively active populations. Those questionnaires such as the FIM (Functional Independence Measure) which was designed for use with a disabled population would not be applicable to a young, able-bodied, active population. We needed a questionnaire which would break tasks down into their basic components which would then be applicable to a wide variety of jobs/activities.

Using features from various questionnaires, we developed our own activity assessment questionnaire. This questionnaire was designed to look at basic elements of tasks such as sitting, standing, walking, typing, etc. and from these elements combined with information on the use of various ambulatory aides, determine an activity level for lower extremity use and upper extremity use which could then be related to the development of overuse symptoms.

- We operationalized the inclusion and exclusion criteria for each of the studies and developed specific plans for subject recruitment. Due to the diverse subject population, we identified a wide variety of sources which included local newspapers, employee newsletters, disability-oriented magazines, polio network and support group newsletters, and the Polio Connection Site on the Internet. We also developed handouts which have been distributed to various churches, VFWs, and athletic clubs in the area. We have also encouraged family members and friends of both our polio and non-polio subjects to participate.

- We selected most appropriate tests for the symptomatology evaluation based on information from the literature and clinical experience. We also established dosage guidelines for interarticular injections based on weight.

- Because of the tremendous number of variables involved, we developed a priori prediction models in order to reduce the risk of Type I error. These prediction models (see Appendix IV) are based on previous findings in the literature and theories of movement compensation.

Each model identifies a potentially problematic muscle or group of muscles and then based on weakness in that muscle(s), predicts the overuse problems which may result.

- We trained the clinical staff (nurse practitioner, nurse liaison, physical therapist, and physical therapy assistant). We collected pilot data in order to determine which type of dynamometer testing (make vs. break) would be most accurate for our diverse subject population. We determined the best way to standardize the testing postures (gravity-resistant vs. gravity-eliminated) and worked out the best way for stabilization of subjects during testing. We finalized the data collection forms and developed a weekly testing schedule which would make optimal use of the clinician's limited time.

  Early results are summarized on the following pages in Tables 1 and 2. Table 1 shows the percentage of polio survivors who reported a specific overuse symptom. As predicted in our a priori models, the results show a relatively high percentage of symptoms in the shoulder, wrist, knee, and foot. Table 2 lists the muscle groups and gives the percentage of polio subjects who have significant weakness in each group as compared to a sample of able-bodied subjects. As expected, the highest percentages of polio survivors who have significant weakness are seen for the muscles of the lower extremities, particularly the ankle and knee. Using these results, we have begun identifying potential subjects for the treatment studies and getting ready to begin that phase of the project.

- The database which will be used for storing subject information, symptoms and strength results over repeated assessments, and for identifying people for the focused studies has been programmed and is in the process of being debugged.

TABLE I. SYMPTOM REVIEW

Location	Symptom Test	Percentage of Positive Responses Recorded for Polio Survivors as of 1/17/97: Right	Left
Shoulder	Biceps palpation	21	21
	Supraspinatus palpation	11	25
	Supraspinatus test	32	36
	Biceps test	0	4
	Int. rotation and adduction	36	29
Elbow	Lat. epicondyle palpation	0	4
	Med. epicondyle palpation	11	4
	Resisted wrist flexion	4	4
	Resisted wrist extension	4	11
Wrist	Wrist palpation	11	7
	Numbness/tingling/arm/wrist/hand	29	29
	Phalens test	11	14
	Tinels test	7	0
	Thenar atrophy	7	18
	Adson's manuever	4	4
Ankle/foot	Ankle/foot palpation	7	14
	PF tenderness/plantar fascia	43	50
	Cavus	54	68
	Equinus	25	25
	Valgus	4	4
Back	Back Palpation	7	4
	Scoliosis	21	18
	Pelvic obliquity	7	11
Hip	Palpation/greater trochanter	7	25
	Resisted abduction	7	11
Knee	PF crepitation (no pain)	43	21
	PF crepitation (pain)	11	14
	Knee valgus	14	21
	ITB contracture	0	0

TABLE II. PRELIMINARY STRENGTH STATISTICS

DOMINANT SIDE:

Muscle Group	Able-bodied Subjects Mean (SD)	Percentage of Polio Subjects Below Mean - 2*SD
Neck extension	31.69 (16.36)	0
Shoulder flexion	33.48 (11.45)	0
extension	36.75 (11.15)	0
ext. rotation	22.23 (6.51)	3
abduction	30.52 (10.92)	7
Elbow extension	34.08 (10.21)	3
flexion	44.02 (12.09)	0
Wrist flexion	26.59 (7.00)	0
extension	24.66 (7.15)	0
Hip flexion	46.59 (12.38)	17
extension	34.74 (10.31)	14
abduction	38.12 (10.61)	14
Knee flexion	37.27 (12.39)	21
extension	44.51 (12.53)	36
Ankle dorsiflexion	37.39 (10.01)	50
plantar flexion	44.60 (10.89)	29

NON-DOMINANT SIDE:

Muscle Group	Able-bodied Subjects Mean (SD)	Percentage of Polio Subjects Below Mean - 2*SD
Neck extension	31.69 (16.36)	0
Shoulder flexion	32.97 (10.24)	3
extension	37.71 (13.43)	0
ext. rotation	23.47 (7.34)	3
abduction	31.54 (10.09)	11
Elbow extension	36.31 (10.65)	7
flexion	45.62 (13.84)	0
Wrist flexion	25.44 (8.08)	3
extension	26.00 (8.86)	3
Hip flexion	44.12 (11.47)	21
extension	36.60 (11.05)	21
abduction	42.13 (11.92)	39
Knee flexion	41.55 (13.06)	32
extension	40.72 (12.04)	36
Ankle dorsiflexion	37.84 (10.69)	57
plantar flexion	46.07 (13.14)	29

- We have completed an extensive literature review of sit-stand tasks. We identified the key issues involved when measuring muscle activity, motion, and force during a sit-stand task. One of these key issues included intial foot and hand position and whether these should be controlled or should we allow for a more "natural" movement. We decided that subjects would be allowed to choose their own hand and foot position, but that these positions would need to be consistent between trials. We defined the variables which will be needed to fully define the movement strategy and determined the moment equations which will be involved. Due to the large number of variables possible in this study, we developed specific prediction models to reduce the risk of Type I error (see Appendix IV).

  The designs for the chair and the platform which will be used in this study have been approved and are in the process of being built. The arms of the chair will be instrumented with triaxial load cells to allow us to get an accurate measure of the force applied by the hands. The platform will be adjustable which will enable us to adjust the seat height as necessary to ensure that the initial task conditions are the same for each subject. The platform will also hold the chair above the force plates on the floor so that the subject will be able to place his/her feet under the chair. This will allow the subject to perform the task in a "natural" way.

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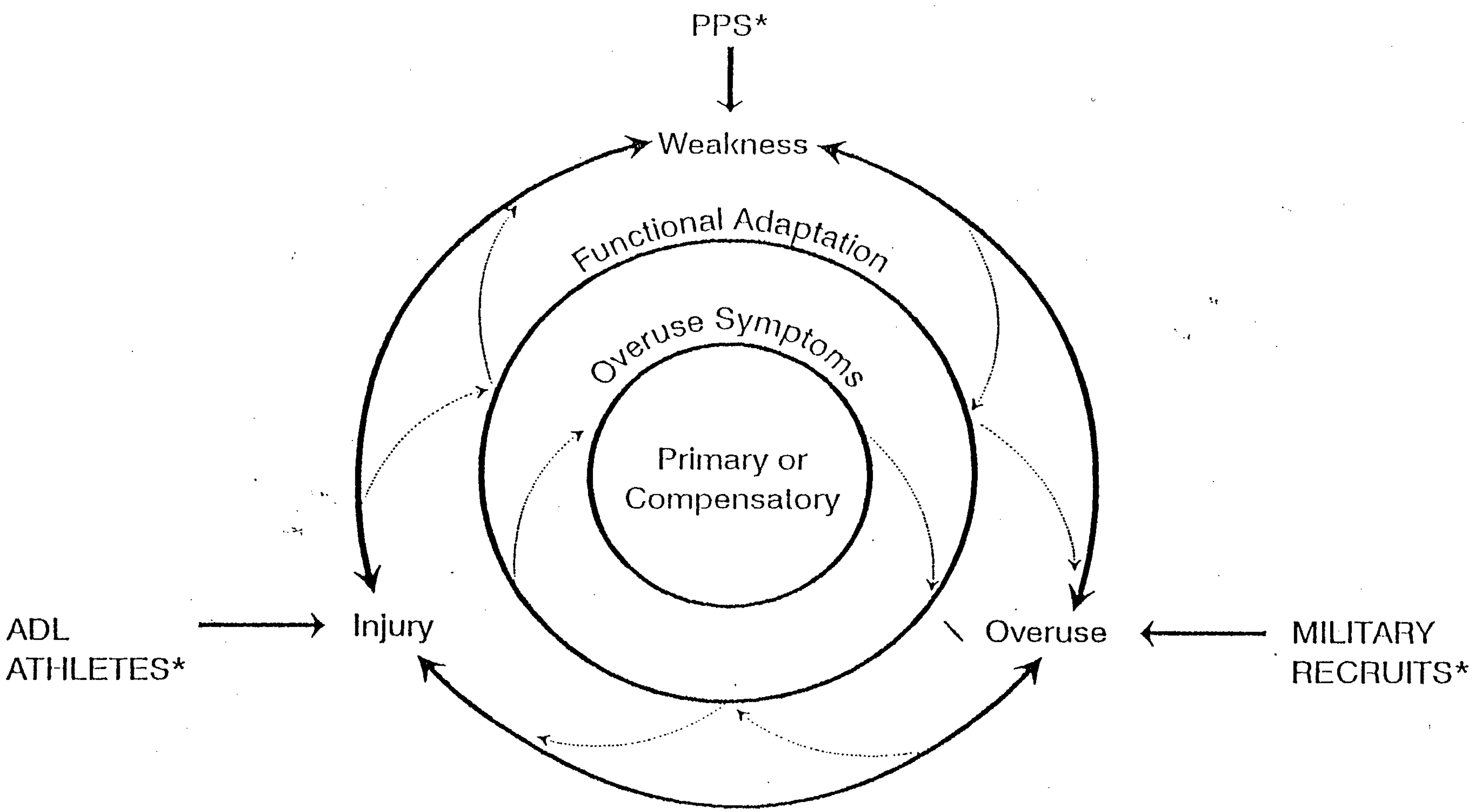
APPENDIX I

Overuse Injuries

Figure 1

The Weakness-Injury-Overuse Cycle



*Patients may enter or exit the overuse symptom cycle at any location, but each patient type is represented at the most common site of entry

Post Polio

Patient Sample Population Survey

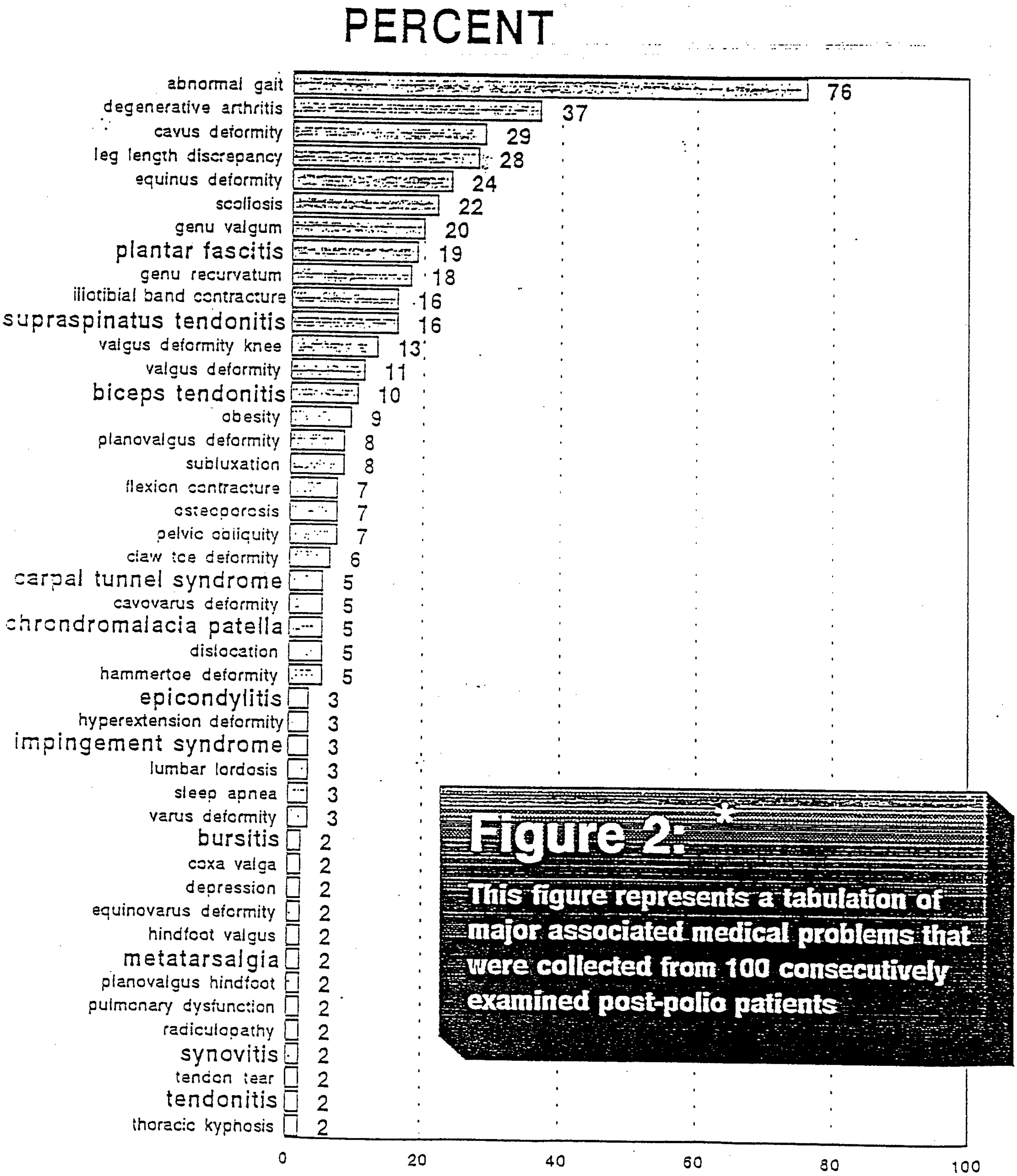


Figure 2: *

This figure represents a tabulation of major associated medical problems that were collected from 100 consecutively examined post-polio patients

* medical problems in bold text are specifically related to the Overuse Syndrome

APPENDIX II

Activity Assessment Form

ACTIVITY ASSESSMENT

This survey is divided into three main sections. The first section deals with work-related activities that are performed outside the home or inside the home for people who are self-employed and run their business from their home. If you are not employed, either outside the home or self-employed, please skip the first section. The second section deals with household activities or work that is performed inside the home. The third section deals with leisure-time activities. Please answer the questions as accurately as you can.

I. OCCUPATION

1) What is your occupation? ____________ Do you have a second job? ____________

How long have you been doing your present type of work? ____________

How many hours per week do you work? ____________

a) At work I sit 1☐ YES 2☐ NO
If yes, approximately how many hours per day?
1☐ less than 2
2☐ 2-4
3☐ 5-8
4☐ more than 8

b) At work I stand 1☐ YES 2☐ NO
If yes, approximately how many hours per day?
1☐ less than 2
2☐ 2-4
3☐ 5-8
4☐ more than 8

c) At work I transfer from sit to stand
1☐ YES 2☐ NO
If yes, approximately how many times/day?
1☐ less than 5
2☐ 5-10
3☐ 11-20
4☐ more than 20

d) At work I walk or I walk to work (either all the way or part way) 1☐ YES 2☐ NO
If yes, approximately how far (in terms of city blocks)?
1☐ less than 2
2☐ 2-4
3☐ 5-8
4☐ more than 8

e) At work I walk up and down stairs
1☐ YES 2☐ NO
If yes, how many flights per day (1 flt = 12 stairs)
1☐ less than 2
2☐ 2-4
3☐ 5-8
4☐ more than 8

f) At work I lift loads (> 10 lbs.) 1☐ YES 2☐ NO
If yes, approximately how many times/day?
1☐ less than 5
2☐ 5-10
3☐ 11-20
4☐ more than 20

g) At work I bend over to pick up objects
1☐ YES 2☐ NO
If yes, approximately how many times/day?
1☐ less than 5
2☐ 5-10
3☐ 11-20
4☐ more than 20

h) At work I reach above my head 1☐ YES 2☐ NO
If yes, approximately how many times/day?
1☐ less than 5
2☐ 5-10
3☐ 11-20
4☐ more than 20

i) At work I carry objects (> 10 lbs.)
1☐ YES 2☐ NO
If yes, approximately how many times/day?
1☐ less than 5
2☐ 5-10
3☐ 11-20
4☐ more than 20

k) At work I type on the computer or typewriter
1☐ YES 2☐ NO
If yes, approximately how many hours per day?
1☐ less than 2
2☐ 2-4
3☐ 5-8
4☐ more than 8

II. HOUSEHOLD ACTIVITIES

This section deals with activities performed when you do chores at home.

Approximately how many hours per week do you work at home? ______________

a) When I do chores at home, I stand

1☐ YES 2☐ NO

If yes, approximately how many hours/day?

1☐ less than 2
2☐ 2-4
3☐ 5-8
4☐ more than 8

b) When I do chores at home, I transfer from sit to stand (from chair, bed, car, or toilet)

1☐ YES 2☐ NO

If yes, approximately how many times per day?

1☐ less than 2
2☐ 2-4
3☐ 5-8
4☐ more than 8

c) When I do chores at home, I walk up and down stairs 1☐ YES 2☐ NO

If yes, how many flights per day (1 flt = 12 stairs)

1☐ less than 5
2☐ 5-10
3☐ 11-20
4☐ more than 20

d) When I do chores at home, I lift loads (> 10 lbs.)

1☐ YES 2☐ NO

If yes, approximately how many times per day?

1☐ less than 5
2☐ 5-10
3☐ 11-20
4☐ more than 20

e) When I do chores at home, I bend over to pick up objects 1☐ YES 2☐ NO

If yes, approximately how many times per day?

1☐ less than 5
2☐ 5-10
3☐ 11-20
4☐ more than 20

f) When I do chores at home, I reach above my head 1☐ YES 2☐ NO

If yes, approximately how many times per day?

1☐ less than 5
2☐ 5-10
3☐ 11-20
4☐ more than 20

g) When I do chores at home, I carry objects (> 10 lbs.)

1☐ YES 2☐ NO

If yes, approximately how many times per day?

1☐ less than 5
2☐ 5-10
3☐ 11-20
4☐ more than 20

h) At home, I do yardwork (i.e. raking leaves, mowing the lawn, shoveling snow) 1☐ YES 2☐ NO

If yes, approximately how many times per month?

1☐ less than 2
2☐ 2-4
3☐ 5-8
4☐ more than 8

i) At home, I work in the garden (i.e. weeding, planting flowers or vegetables) 1☐ YES 2☐ NO

If yes, approximately how many times per month?

1☐ less than 2
2☐ 2-4
3☐ 5-8
4☐ more than 8

j) At home, I sweep and mop the floors 1☐ YES 2☐ NO

If yes, approximately how many times per month?

1☐ less than 2
2☐ 2-4
3☐ 5-8
4☐ more than 8

k) At home, I do the laundry 1☐ YES 2☐ NO

If yes, approximately how many loads per week?

1☐ less than 2
2☐ 2-4
3☐ 5-8
4☐ more than 8

l) At home, I vacuum the rugs 1☐ YES 2☐ NO

If yes, approximately how many times per month?

1☐ less than 2
2☐ 2-4
3☐ 5-8
4☐ more than 8

m) At home, I clean the windows 1☐ YES 2☐ NO

If yes, approximately how many times per month?

1☐ less than 2
2☐ 2-4
3☐ 5-8
4☐ more than 8

III. LEISURE

a) During leisure time I watch television, watch videos or read 1☐ YES 2☐ NO

If yes, approximately how many hours per week?

1☐ less than 5
2☐ 5-10
3☐ 11-20
4☐ more than 20

b) During leisure time I walk (around the block, shopping)

1☐ YES 2☐ NO

If yes, approximately how many minutes do you walk/day?

1☐ 5-10
2☐ 11-15
3☐ 16-20
4☐ more than 20

How many days per week? ____________

c) During leisure time I jog and/or run 1☐ YES 2☐ NO

If yes, how many minutes do you jog and/or run per day?

1☐ 5-10
2☐ 11-15
3☐ 16-20
4☐ more than 20

How many days per week? ____________

d) During leisure time I cycle 1☐ YES 2☐ NO

If yes, how many minutes do you cycle per day?

1☐ 5-10
2☐ 11-15
3☐ 16-20
4☐ more than 20

How many days per week? ____________

e) During leisure time I swim 1☐ YES 2☐ NO

If yes, how many minutes do you swim per day?

1☐ 5-10
2☐ 11-15
3☐ 16-20
4☐ more than 20

How many days per week? ____________

f) During leisure time I go dancing (square dancing, ballroom dancing, etc.) 1☐ YES 2☐ NO

If yes, approximately how many hours per week?

1☐ less than 5
2☐ 5-10
3☐ 11-20
4☐ more than 20

g) During leisure time I do calisthenic or aerobic exercises

1☐ YES 2☐ NO

If yes, how many minutes do you exercise per day?

1☐ 5-10
2☐ 11-15
3☐ 16-20
4☐ more than 20

How many days per week? ____________

h) During leisure time I do stretching exercises or yoga

1☐ YES 2☐ NO

If yes, how many minutes do you exercise per day?

1☐ 5-10
2☐ 11-15
3☐ 16-20
4☐ more than 20

How many days per week? ____________

i) During leisure time I sew (knit, crosstitch, needlepoint, crochet) or do crafts 1☐ YES 2☐ NO

If yes, how many hours per week?

1☐ less than 5
2☐ 5-10
3☐ 11-20
4☐ more than 20

j) During leisure time I work on my car 1☐ YES 2☐ NO

If yes, approxiamtely how many hours per week?

1☐ less than 5
2☐ 5-10
3☐ 11-20
4☐ more than 20

k) During leisure time I do things on my computer (games, Internet etc.) 1☐ YES 2☐ NO

If yes, how many hours per week?

1☐ less than 5
2☐ 5-10
3☐ 11-20
4☐ more than 20

l) During leisure time I play a sport 1☐ YES 2☐ NO

a. If yes,what sport do you play most frequently? ____________

b. How many hours per week? ____________ hrs/wk

c. How many months per year? ____________ months/year

d. Do you play a second sport? 1☐ YES 2☐ NO
If yes, what sport is it? ____________

APPENDIX III

Muscle Testing

Tests for Overuse Symptoms and Deformities

Location	Test
Shoulder	Biceps palpation Supraspinatus palpation Supraspinatus test (impingement w/ resistance) Biceps test (resistive supination of forearm) Int. rotation and adduction (ant.capsule)
Elbow	Lat. epicondyle palpation Med. epicondyle palpation Resisted wrist flexion Resisted wrist extension
Wrist	Palpation Numbness/tingling/arm/wrist/hand Phalens test Tinels test Thenar atrophy Adson's maneuver
Ankle/Foot	Palpation PF tenderness/plantar fascia Cavus Equinus Valgus
Back	Palpation Scoliosis Pelvic obliquity
Hip	Palpation (greater trochanter) Resisted abduction
Knee	PF crepitation Knee valgus ITB contracture

STRENGTH TESTING PROTOCOL

Muscle Group	Body Position	Position of Limb	Dynamometer Placement	Stabilization Point
Shld. Ext. Rotation	Sitting	Shoulder at neutral; elbow flexed 90°	Just proximal to ulnar styloid	Contralateral shoulder
Wrist Flexion	Sitting	Shoulder at neutral; elbow flexed 90°	Dorsal aspect of hand	Forearm
Wrist Extension	Sitting	Shoulder at neutral; elbow flexed 90°	Palmar aspect of hand	Forearm
Shld. Abduction	Supine	Shoulder abducted to 90°	Midshaft of humerus	Anterior aspect of shoulder
Hip Abduction	Supine	Hip abducted to 45°; with contralateral hip in neutral	Proximal to superior pole of patella on lateral aspect of thigh	Hip
Ankle D. Flexion	Supine	Hip, knee, and ankle at 0°	Metatarsals	Tibia
Ankle P. Flexion	Supine	Hip, knee, and ankle at 0°	Metatarsal heads	Tibia
Neck Extension	Sidelying	Neck at neutral	Base of skull	None
Shld. Flexion	Sidelying	Shoulder flexed 90°; elbow extended	Midshaft of humerus	Anterior aspect of shoulder
Shld Extension	Sidelying	Shoulder at neutral; elbow flexed 90°	Proximal to olecranon	Anterior aspect of shoulder
Elb. Extension	Sidelying	Shoulder at neutral; elbow flexed 90°	Proximal to ulnar styloid; dorsal surface of forearm	Shoulder

STRENGTH TESTING PROTOCOL CONTINUED

Muscle Group	Body Position	Position of Limb	Dynamometer Placement	Stabilization Point
Elb. Flexion	Sidelying	Shoulder at neutral; elbow flexed 90°	Palmar surface of forearm; proximal to wrist	Shoulder
Hip Flexion	Sidelying	Leg positioned on raised powder board; hip flexed to 30°; knee flexed	Proximal to superior side of patella	Pelvis
Hip Extension	Sidelying	Leg positioned on raised powder board; hip neutral; knee extended	Proximal to popliteal crease	Pelvis
Knee Flexion	Sidelying	Leg positioned on raised powder board; hip flexed 10°; knee flexed 30°	Proximal to maleoli on posterior aspect of calf	Anterior aspect of femur
Knee Extension	Sidelying	Leg positioned on raised powder board; knee flexed 45°	Proximal to malleoli on anterior aspect of tibia	Femur

APPENDIX IV

Prediction Models

KINESIOLOGIC BASIS OF ORTHOPAEDIC PROBLEMS IN POST-POLIO SYNDROME

1. Weakness of the gastrocnemius and soleus muscles results in increased muscular demand on the quadriceps muscle. This is the etiology of knee pain with quadriceps tendinitis and patella-femoral crepitation or arthritis.

   Translation: Ankle plantar flexion strength < 5 (assuming knee extensor strength ≥ 4 and no articulating brace with dorsiflexion stop). Positive symptoms in knee for PF crepitation. (All above in one leg.)

2. Average weakness of the hip and knee extensor muscle in the lower extremities causes individuals to lean heavily on their arms when rising from a seated position (assuming moderate to strong arms). This is the theoretical etiology of supraspinatus and biceps weakness, tendinitis, and rotator cuff pathology.

   Translation: hip and knee extensor strength < 5plus weakness in shoulder depressors (flexors and abductors) or strength < 5. Positive symptoms for palpation of biceps and/or supraspinatus

3. A cavus deformity of the foot places increased strain on the plantar fascia during standing and walking. This is the etiology of plantar fascitis and metatarsalgia.

   Translation: A foot with a high arch (positive for cavus deformity) is caused by an imbalance of muscles (i.e. toe flexor strength is greater than toe extensor strength). Positive symptoms for PF tenderness. All in one leg. This will be true for walkers only, with no crutches, and no braces with shoe insert and/or dorsi-stop.

4. A fixed equinus deformity of the ankle results in a hyperextension thrust on the knee during standing and walking . This results in hamstring tendinitis and possible genu recurvatum.

   Translation: ankle plantar flexion and knee extensor strength < 5. Positive for equinus deformity. This is for walkers only, without braces that limit knee extension to 0-5°.

PREDICTION MODELS CONTINUED

5. Use of crutches, walkers, or other upper extremity aides for ambulation causes carpal tunnel syndrome. Also seen when pushing up from a wheelchair.

   Translation: Positive responses for use of crutches, walker, cane, or wheelchair. Positive symptoms for one or more of following:

   Phalen's test
   Tinel's test
   Thenar atrophy
   Numbness/tingling of arm, hand, and/or wrist
   Palpation

6. Hip abductor weakness, leg length, leg length inequality or valgus positioning of the hindfoot cause a valgus force on the knee during walking and will eventually result in a valgus deformity of the knee. This is true for walkers only, with no shoe lift or cane use with the opposite arm.

   Translation: Hip abductor weakness < 5, positive for leg length inequality or valgus deformity of foot. Positive for valgus deformity of knee.

7. Ipsilateral hip abductor weakness results in hip tendinitis.

   Translation: Hip abductor weakness <5 and positive for trochanter tenderness.

POST-POLIO PROJECT
A PRIORI PREDICTIONS FOR SIT-STAND TASK

Data Type:	Condition1 (C1) Hip 90°, no arms	Condition2 (C2) Hip 90°, with arms	Condition3 (C3) Hip 70°, with arms
Force	Less force under weak leg/ more under stronger leg; more force on seat	More force in arms; more force under good leg (but less than in C1); more force on seat but less than in chair w/no arms (C1)	Less arm force than for 90° chair (C2); more force under weaker leg than for other chairs (or at least earlier onset); less ground shear force (during forward momentum phase?, but overall GRF should be ~same since low accelerations in STS) less force on seat of chair
Motion	More forward trunk/hip flexion; trunk shifted over knees; feet farther back and more ankle dorsiflexion; arms in front of them	Less trunk forward flexion than for chair w/no arms (C1); less dorsiflexion (feet less back than in C1); perhaps use contralateral hand on rest, ipsilateral hand on weak leg to help stabilize knee	Even less forward hip flexion; less ankle dorsi-flexion; more symmetrical release of arms from chair
Muscle Activity	Initially use more contra-lateral hip and ankle plantar flexors; more ipsilateral hip extensor and ankle plantar activity in last 2 phases; increased activity in weak leg	Overall less activity in legs; overall increase in activity in arms compared to same chair without arms (C1)	Decrease in leg and arm activity compared to other chairs (C1,C2)