DEFENSE TECHNICAL INFORMATION CENTER
REQUEST FOR SCIENTIFIC AND TECHNICAL REPORTS

Title
Changes in Strength Over Time Among Polio Survivors

1. Report Availability (Please check one box)
☐ This report is available. Complete sections 2a - 2f.
☐ This report is not available. Complete section 3.

2a. Number of Copies Forwarded
1

2b. Forwarding Date
4-5-2000

2c. Distribution Statement (Please check ONE box)

DISTRIBUTION STATEMENT A: Approved for public release. Distribution is unlimited.

☐ DISTRIBUTION STATEMENT B: Distribution authorized to U.S. Government Agencies only.

☐ DISTRIBUTION STATEMENT C: Distribution authorized to U.S. Government Agencies and their contractors.

☐ DISTRIBUTION STATEMENT D: Distribution authorized to U.S. Department of Defense (DoD) and U.S. DoD contractors only.

☐ DISTRIBUTION STATEMENT E: Distribution authorized to U.S. Department of Defense (DoD) components only.

☐ DISTRIBUTION STATEMENT F: Further dissemination only as directed by the controlling DoD office indicated below or by higher authority.

☐ DISTRIBUTION STATEMENT X: Distribution authorized to U.S. Government agencies and private individuals or enterprises eligible to obtain export-controlled technical data in accordance with DoD Directive 5230.25, Withholding of Unclassified Technical Data from Public Disclosure, 6 Nov 84.

2d. Reason For the Above Distribution Statement (in accordance with DoD Directive 5230.24)

2e. Controlling Office
Army Research

2f. Date of Distribution Statement Determination

3. This report is NOT forwarded for the following reasons. (Please check appropriate box)

☐ It was previously forwarded to DTIC on _/__/____ and the AD number is ________________.

☐ It will be published at a later date. Enter approximate date if known. ________________.

☐ In accordance with the provisions of DoD Directive 3200.12, the requested document is not supplied because:

Mary Klein, Ph.D.
(215) 456-7864

Signature
Mary Klein

Print or Type Name

DTIC QUALITY INSPECTED 2

TOTAL P. 02
Changes in Strength Over Time Among Polio Survivors

Mary G. Klein, PhD;¹ John Whyte, MD, PhD;²,⁴ Mary Ann Keenan, MD¹,⁴
Alberto Esquenazi, MD;³,⁴ Marcia Polansky, ScD⁵

¹) Albert Einstein Medical Center; ²) Moss Rehabilitation Research Institute;
³) MossRehab Hospital; ⁴) Temple University School of Medicine
⁵) MCP-Hahnemann University

Philadelphia, PA

Supported by grant DAM17-95-1-5079 from the U.S. Department of the Army.

Reprint requests to Mary G. Klein, Korman 204-B, Moss Rehabilitation Research Institute, 1200
West Tabor Road, Philadelphia, PA 19141; Phone: 215-456-7864, FAX: 215-456-9514.
ABSTRACT

Objective: To study changes in the strength of a variety of muscle groups in polio survivors over a 6-9 month period.

Design: Longitudinal study of a cohort of polio survivors

Setting: A research laboratory at Moss Rehabilitation Research Institute

Participants: One hundred twenty subjects (57 men and 63 women) were studied on three occasions, each 3-5 months apart. Subjects were recruited through the Einstein-Moss Post-Polio Management Program, newspaper advertisements, and polio support groups. Demographic, medical history data, and strength data were obtained. Subjects were classified based on whether or not they reported subjective feelings of increasing weakness at the initial visit.

Main Outcome Measures: Isometric strength of 30 muscle groups (16 in upper extremities and 14 in lower extremities) was measured using a hand-held dynamometer.

Results: The data were analyzed in two separate groups: upper extremity muscles and lower extremity muscles. Results for the upper extremity muscles revealed evidence of a significant deterioration in strength over the study interval. The amount of deterioration differed among muscles. The results also showed that the rate of deterioration increased with increasing age.

For the lower extremities, there was also evidence of deterioration in strength in the flexor muscles of the ankle, hip, and knee. The rate of deterioration in these muscles was not strongly related to age, gender, symptom status, or history of residual weakness.

Conclusions: Our results indicate that strength is deteriorating among polio survivors. However, this deterioration is not occurring in the extensor or so-called "weight-bearing" muscles, but is instead occurring in many of the upper extremity muscle groups and in the flexor muscles in the lower extremities.
INTRODUCTION

Post-polio syndrome (PPS) is a term used to describe a collection of symptoms experienced by many polio survivors after several decades of functional stability. These symptoms include muscle and joint pain, muscle weakness, fatigue and intolerance to cold.\textsuperscript{1,2,3} Several functional and pathophysiologic mechanisms have been suggested for PPS, but none has been proven. There is some controversy regarding whether the symptoms involved are due to the primary degeneration of motor units previously affected by polio versus the attrition of motor neurons associated with normal aging.\textsuperscript{4,5,6} Another theory involves overuse or "overwork weakness" where the functional demands exceed the capacity of polio-affected muscles.\textsuperscript{7} Other authors have suggested that disuse may play an important role, while still others have suggested that increased stress due to weight gain may be an important factor.\textsuperscript{8,9,10}

Currently, there is no diagnostic test for PPS. It is usually diagnosed by excluding other medical or neurological disorders that may produce similar symptoms. For example, the symptoms experienced by polio survivors with PPS are similar to those experienced in patients with chronic fatigue syndrome.\textsuperscript{11} Fibromyalgia is another neuromuscular disorder with similar symptoms, which is common among middle-aged, deconditioned persons. It is possible that the chronic use of weakened muscles or the compensatory use of other muscles with "normal" levels of strength may predispose polio survivors to this type of disorder.\textsuperscript{11}

Post-polio syndrome is believed to be slowly progressive. Previous studies have examined whether strength decreases at an accelerated rate over time in polio survivors. These studies have followed the strength in polio survivors over periods ranging from one year to just over eight years with contradictory results (Table 1).
Several of these studies focused on symptomatic polio survivors, or those who reported increasing muscle weakness (Dalakas, et al, 1986; Musat et al., 1987; Munin et al., 1991) while others have compared symptomatic (unstable) with asymptomatic (stable) polio survivors (Grimby et al., 1994, Ivanyi et al., 1996, Rodriquez et al., 1997). In each case, the results have been inconsistent with some studies reporting significant decreases in strength, others reporting no significant change, and still others reporting evidence of an increase in strength, even among those subjects who are reporting subjective feelings of increasing weakness.

In addition, most of the previous studies have limited their testing to only one or two muscle groups. The assumption is made that these muscle groups are representative of polio-affected muscles throughout the body. As shown in Table 1, many of the researchers have focused their attention on the quadriceps muscle in one leg that was affected by polio. What is not taken into account is the cumulative effects over time on the muscles which are used to compensate for those muscles left weakened by the polio virus. The one study, which did look at a fairly extensive list of muscle groups, reported a significant increase in isometric strength in 10 out of 22 muscle groups among subjects who were reporting problems with increasing muscle weakness. The authors gave no explanation for this contradictory conclusion.

It is evident that more research is needed on the changes in the muscle strength of polio survivors over time in order to clarify some of these contradictions. The purpose of this study was to assess the strength of polio survivors in a comprehensive group of muscles and to determine whether there was a significant decrease in muscle strength over time. Gravity-
eliminated positioning was used for the strength testing in order to enable us to include a more representative sample of the post-polio population.

METHOD

A total of 120 polio survivors (57 men and 63 women) participated in this study. Subjects were recruited through the Einstein-Moss Post-Polio Management Program, post-polio support groups, and advertisements in local newspapers. Inclusion criteria for all subjects were:

1) history of polio; 2) no other major disabilities, such as stroke, amputation, inflammatory arthritis, or peripheral neuropathy, that could cause muscle weakness; 3) no serious illnesses, such as severe emphysema, poorly controlled asthma, resting angina, or a recent heart attack, which would make a maximal strength test unsafe; and 4) no fractures or surgeries within the past six months, which might cause transient changes in strength. All subjects gave informed consent, and the hospital's Institutional Review Board approved the study protocol.

At the initial visit, each subject was asked to complete a standardized medical history form and a polio history questionnaire. As part of the polio history questionnaire, subjects were asked to specify their age at the time of the acute infection and the sites where they were left with residual weakness or paralysis. The seven possible sites were: neck, back, abdomen, left arm, left leg, right arm or right leg. Subjects were also asked if they had recently been experiencing problems with increasing weakness. Subjects who reported increasing weakness were classified as symptomatic and those who did not were classified as asymptomatic.

Following completion of the forms, height (cm) and weight (kg) were assessed using a standard scale. Isometric strength was then measured in 15 muscle groups bilaterally by one of three physical therapists using a Microfet2\textsuperscript{a} hand-held dynamometer (HHD). The muscle groups...
involved were: wrist flexors and extensors, elbow flexors and extensors, shoulder abductors, external rotators, flexors, and extensors, hip abductors, flexors, and extensors, knee flexors and extensors, and ankle dorsiflexors and plantarflexors. All muscles were tested in gravity_eliminated positions. The postures, placement of the dynamometer, and stabilization points were standardized (Table 2). For each test, the subject pushed against the padded dynamometer force plate that the physical therapist held stationary. The subject was asked to slowly build to a maximal force over a period of 2-3 seconds and then hold this maximal effort for 3-4 seconds.

The peak force was measured in pounds. Each muscle group was measured a minimum of two times. Additional measurements were taken only if the first two varied by more than 10%. For very weak muscles with strengths less than 10 lb., measurements were repeated only if the difference between the first two measurements was greater than 1 lb. The maximum number of trials was four to prevent fatigue. If a subject reported any muscle or joint pain during testing, those trials were considered invalid. For each muscle group, the average of the valid trials was defined as the isometric maximal voluntary contraction (MVC). Muscle groups whose strength was equal to zero at the initial visit were not included in any of the analyses.

After the initial visit, subjects returned to the Research Clinic two additional times at approximately the same time of day to have their strength reassessed. A period of 3-5 months separated each visit.

Insert Table 2 about here.
Interrater reliability of the three physical therapists was determined for each of the muscle groups. Six subjects (2 polio survivors and 4 individuals with no history of polio) participated in the reliability testing. The strength of each of the 15 muscle groups was tested twice bilaterally by each of the three physical therapists. The average of the two maximal efforts was used for analysis. All strength measurements for a particular subject, gathered for reliability purposes, were performed at the same time of day within a one-month time period.

DATA ANALYSIS

Data were analyzed using the SYSTAT7™ software package. The appropriate descriptive statistics were used to describe the study participants. Intraclass correlation coefficients (ICC[3,1]) were used as indices of reliability for the strength measurements.

Repeated measures multivariate analysis of variance (MANOVA), with muscle and time as the repeating factors, was used to determine whether strength changed significantly over time. The original design was to look at general weakening over the entire body. However, a majority of the subjects had missing data or one or more invalid strength values (i.e. due to either pain during measurement or an initial strength value of zero) for at least one muscle group, resulting in their exclusion from the MANOVA. Therefore, we arbitrarily divided the muscles into two groups, upper extremity muscles and lower extremity muscles, in order to increase the sample size for analysis. Out of the 120 subjects who participated in this study, 71 subjects had complete data for the upper extremity group and 65 subjects had complete data for the lower extremity muscle group. There were 40 subjects who had complete data for all muscles and were included in both groups, and 23 subjects who were not included in either group. Based on plots of the various data, which revealed highly skewed distributions, all data were ranked prior...
to analysis. The strength data were ranked separately within each muscle, across time.

Post-hoc analyses included effect sizes\textsuperscript{22} that were calculated based on the difference
scores (mean of the strength at visit 1 minus strength at visit 3 across subjects divided by the
standard deviation of the differences) for each muscle, using the raw data. The purpose of this
analysis was to determine which muscles showed the greatest change in strength and in what
direction. In addition, robust slopes were calculated for each subject by muscle using nonlinear
regression. This gave us a measure of the rate of change in strength for each individual muscle
in each subject. The average slope was then calculated for each subject across all left-sided
muscles to get a measure for the slope for the left limb. A similar procedure was followed for
the right-sided muscles and finally, across all muscles in each group (i.e. upper vs. lower).
Visual inspection of plots and comparison of the means and medians of the slopes for the various
muscles showed no evidence of any skewed distributions. Therefore, all analyses done with
slopes were parametric.

An analysis of covariance (ANCOVA) was performed for each group with the mean
overall slope as the dependent variable and age, gender, weight, and symptom status (i.e.
subjects who reported increasing weakness on the polio history form were classified as
symptomatic and all others were asymptomatic) as the covariates. Separate ANCOVAs were
also performed on each limb with "history of residual weakness in that limb (yes/no)" as a
covariate, along with any covariates that were identified as significant predictors for the group
slope. Statistical significance for all analyses was defined as p < 0.05.
RESULTS

Reliability Testing

All ICC values for interrater reliability of the strength measurements ranged from 0.522 to 0.987, with a median of 0.850. All values were above 0.7 except for right ankle plantar flexion, which had a value of 0.522. The range in ICC values seen in this study is similar to that seen in another study that used a hand-held dynamometer and multiple testers to measure strength in various muscle groups and reported ICCs that ranged from 0.511 to 0.950.¹⁰

Upper Extremity Strength

The characteristics of the subjects in the upper extremity group are displayed in Table 3. The range in age was 38 to 81 years. The median age at onset of polio was 4 years, and the median number of years since polio was 48, ranging from 38 to 80 years. There were 48 symptomatic subjects and 23 asymptomatic subjects included in this group. A total of 12 (17%) subjects reported residual weakness from the original polio infection in their right arm, and 17 (24%) reported residual weakness in their left arm. In addition, 4 (6%) subjects reported weakness in both arms and 46 (65%) subjects reported no residual weakness in either arm.

Results of the repeated measures MANOVA on upper extremity strength showed that the main effect of time (p < 0.001) was highly significant. The mean upper extremity slope across all subjects was negative, which indicated a deterioration in upper extremity strength over time. The results of the MANOVA also revealed a significant muscle by time interaction (p < 0.001), indicating that strength decreased more rapidly in some muscles than in others. In order to determine which muscles showed the greatest change in strength over time, parametric effect sizes were calculated across subjects for each muscle. A positive effect size was indicative of a
decrease in strength over time. As shown in Table 4, all the upper extremity muscles had positive effect sizes. However, these effect sizes ranged from large to small. The largest effect sizes were seen for the right wrist flexor and the left shoulder external rotator.

The results of the ANCOVA on the mean upper extremity slope, with age, gender, symptom status, and weight as covariates, indicated that age was the only significant factor (p = 0.036). Age and upper extremity slope were plotted with a linear smoother to show the trend in the relationship between the two variables (Figure 1). As age increased the mean upper extremity slope decreased, indicating an increasing rate of deterioration of strength with increasing age. Age and history of residual weakness in that limb (yes or no) were then input as covariates in separate ANCOVAs for the left and right arms in order to determine if history significantly affected the rate of deterioration of strength. In both arms age was marginally significant (left arm: p = 0.081; right arm: p = 0.050). However, history of residual weakness was not a significant factor for predicting the slope in either arm (left arm: p = 0.191; right arm: p = 0.587).
Lower Extremity Strength

The characteristics of the subjects in the lower extremity group are displayed in Table 5. The range in age was 38 to 76 years. The median age at onset of polio was 5 years, and the median number of years since polio was 48, ranging from 38 to 72 years. There were 43 symptomatic subjects and 22 asymptomatic subjects included in this group. A total of 38 (58%) subjects reported residual weakness from the original polio infection in their right leg and 26 (40%) reported residual weakness in their left leg. In addition, 10 (15%) subjects reported residual weakness in both legs and 11 (17%) subjects reported no residual weakness in either leg.

Results of the repeated measures MANOVA on lower extremity strength indicated that the main effect of time (p = 0.002) was significant. The interaction between muscle and time was also significant (p < 0.001), indicating that the change in strength over time varied among muscles. Once again, parametric effect sizes were calculated for each muscle (Table 6). The largest effect sizes were seen for the flexor muscles, including the bilateral ankle dorsiflexors, bilateral knee flexors, and bilateral hip flexors, indicating that these muscles showed the largest deterioration in strength. However, the weight-bearing muscles generally showed stable or slightly increasing strength over the study interval.

Similar to the results for the upper extremity group, the mean slope for the lower extremity muscles across all subjects was negative indicating an overall deterioration in strength. Results of the ANCOVA with lower extremity slope as the dependent variable and age, gender,
weight, and symptom status as the covariates showed that none of the covariates were significant. Separate ANCOVAs were performed on the slopes for the left and right legs, with history of residual weakness in each leg (yes/no) as the covariate. History was not a significant factor for either leg (left leg: \( p = 0.882 \); right leg: \( p = 0.720 \)).

In order to determine if there was any evidence of an age effect in the lower extremities, even at a descriptive level, we compared the mean slopes for the lower extremities overall and for the six muscle groups that showed the largest degree of deterioration for two different age groups: a “young” group aged 40-50 years and an “old” group aged 60-70 years (Table 7). The results showed that while the “old” group had a more negative slope, representing a higher rate of deterioration, in the lower extremities overall and in four of the six muscle groups, none of the differences were significant (all \( p > 0.05 \)).

DISCUSSION

Most of the studies that have looked at changes in strength over time among polio survivors have focused their analysis on only one or two muscle groups.\(^{10,15-18,20}\) Most often, the quadriceps or knee extensors are chosen because they are easily isolated for testing, the testing reliability is generally high, and there are many other studies that involve these muscle groups to refer to for comparison.\(^{15,23}\) In addition, the assumption is made that since the polio virus often affected these muscles, they may, as a result, be overworked. However, the results
from these studies are contradictory and leave some question as to whether polio survivors are
losing strength at an accelerated rate compared to the general population. There is also some
question as to whether the results of from one muscle group can be applied to other muscle
groups.

By including a wide range of muscle groups in this study, we were able to look at the
strength of the upper body and lower body as a whole in order to determine if there were any
signs of overall weakening. Although our study only covered a period of 6-9 months, the results
provided objective evidence that muscle strength is deteriorating in polio survivors.

As mentioned earlier, there have been a number of theories proposed to explain
deteriorating strength and other symptoms associated with PPS. For example, it has been
suggested that the enlarged motor units in polio-affected muscles are more vulnerable to
repetitive trauma or overuse than normal muscle units. One theory involves the ratio of
muscle fibers to motor neurons in different muscles. Muscles in the upper extremities, which
require fine control, such as those in the hand, have motor neurons that may supply hundreds of
muscle fibers. However, in the larger muscles in the lower extremities, one motor neuron may
innervate thousands of muscle fibers. Therefore, if the polio virus affected one of these lower
extremity muscles, a motor neuron, which originally supported three or four thousand muscle
fibers, may have ended up supporting tens of thousands of muscle fibers. Consequently, the loss
of motor neurons in larger muscles will have a more significant effect than the loss of the same
number of neurons in smaller muscles, like a finger flexor.

Loss of neurons may result from attrition associated with normal aging or as a result of
overuse, when the functional demands exceed the capacity of polio-affected muscles. If, in fact,
the deterioration in strength was due to "normal" aging, you would expect to see either similar
rates of decline in all lower extremity muscles or a higher rate of decline in the muscles most
often affected by the polio virus (e.g. the quadriceps or knee extensor muscles). However, the
results of this study showed evidence of deterioration of strength in the hip, knee, and ankle
flexor muscles rather than the knee extensor muscles.

We can infer that this pattern of deterioration is due to overuse. While there are
strategies or "tricks" people can use to compensate for weak extensor muscles, there is no way to
protect the flexor muscles, other than not to use them. For example, people may lean against the
joint capsule, ligaments etc. to stabilize the knee joint while standing. This saves extensor
muscle activity and energy and is also efficient. Polio survivors are masters of this art. Braces
are also used in this way to provide external support for weak extensor muscles (e.g. an ankle
foot orthosis may limit dorsiflexion to neutral to stabilize a weak calf in the terminal stance
phase of gait).

However, there is no substitute for the flexor muscles in lifting a leg against gravity to
take a step forward. Therefore, the swing phase or flexor muscles that lift the leg are subject to
repetitive stresses that cannot be prevented or reduced with braces or crutches. In fact, when
braces are used it is important to consider their weight since they put additional strain on the
swing (flexor) muscles, especially when they are at the end of the leg, which acts as a long lever
arm relative to the hip.

The results also showed evidence of a deterioration in strength in all the upper extremity
muscles measured. The changes did not follow an obvious pattern (i.e. in terms of similar types
of muscles changing at similar rates etc.). This is actually not an unexpected finding since the
upper extremities do not perform repetitive, stereotypical activities like the legs. Upper
extremity strength can be affected by different types of activities and activity levels, hand
dominance, use of assistive devices (e.g. canes, crutches), use of manual wheelchair, and the inter-relationships among the muscles in the ipsilateral or contralateral arm.

Although gender, weight, and symptom status have been identified in previous studies as being significant predictors of absolute strength, our results showed that none of these variables were significant predictors of the rate of change in strength for either the upper or lower extremity muscles. In addition, history of residual weakness was not a significant factor for determining the rate of change in strength in either the arms or legs.

Most of the previous studies that looked at the strength in polio survivors over time required their subjects to have strength equal to grade 3+ or greater in the muscle being tested (i.e. gravity-resistant strength). Reasons for this criterion included that the method of testing required gravity-resistant strength, and the investigators felt that it would be too difficult to detect changes in strength in weaker muscles. In the present study, gravity-eliminated testing positions were used which enabled us to include subjects with all levels of strength. This meant that our study population was more representative of polio survivors overall than in many other studies of this type. The only muscle groups that were excluded from the analysis were those with initial strengths equal to zero, since the strength of these muscles would not be expected to change and might otherwise skew the data. Despite the fact that our population included these weaker subjects, we still found evidence of a significant deterioration in strength in the upper and lower extremities.

In addition, most of the previous studies limited their study populations to subjects who were 65 years or younger at the time of the initial evaluation. The population in the current study included subjects who ranged from 38 to 81 years of age. Our results showed that, while age was a significant predictor of deterioration of upper extremity strength, it did not show up as
a significant predictor of the rate of deterioration of lower extremity strength. However, there
was evidence of an age effect at the descriptive level. However, while the trend was for the older
subjects to have a higher rate of deterioration in strength, none of the group differences were
significant. It is possible that the age effect in the lower extremities was not as robust as that
seen in the upper extremities due to more noise in the data (i.e. there was more variability in
strength in the lower extremity muscles). However, it is also possible that since the lower
extremities were often affected by the polio virus to a greater degree than the upper extremities,
that the rate of deterioration in these muscles is actually related an interaction between the
absolute level of strength and activity level rather than age. Unfortunately, the activity survey
used in this study gave us only a gross measure of daily activity. Better measures of activity
level and information on direct use are needed in order to accurately determine what activities
are linked to deterioration of strength and the development of overuse problems in the post-polio
population.

Further research is also needed in this area involving larger population samples for longer
periods of time. These studies need to go beyond the muscle groups traditionally focused on and
look at the long-term changes in the strength of muscles like the flexor muscles in the legs and
upper extremity muscles in general. This research is especially important to the post-polio
population since good upper extremity function allows many polio survivors to remain active
and relatively independent even if their ability to ambulate is lost or severely limited. In addition,

studies are needed on the effects of exercise programs and other rehabilitation interventions
designed to focus on these muscles in order to determine whether such treatments can effectively
slow or even reverse the deterioration process. Also needed is information on the effects of such

a program on the subjective feelings of increasing weakness among polio survivors.
CONCLUSIONS

The results of our study suggest that strength is deteriorating among polio survivors and that the muscles most involved are not those that are studied by the majority of researchers. Evidence of a more rapidly progressive decrease in strength with increasing age was seen in the upper extremities. There was also evidence of a decrease in strength of the flexor muscles in the lower extremities for all subjects regardless of age, gender, or weight. These results have interesting implications for treatment programs designed to help polio survivors conserve or improve their existing muscle strength to help them maintain their independence for as long as possible.

Acknowledgments: The authors would like to express our sincere thanks to Roberta Costello, RN, Jeannine Jacobs, RN, Julie Nagorsky, PT, Chris Palmer, PTA, and Steve Sepel, PT for their time and effort in data collection. We gratefully acknowledge Yvonne Randolph for her work in recruiting and scheduling subjects. We would also like to thank our subjects, without whom this study could not have been done.

References


4. Trojan DA, Cashman N, Shapiro S, Tansey CM, Esdaile JM. Predictive factors for post-

5. Dalaskas MS. Pathogenic mechanisms of post-polio syndrome: morphological,
electrophysiological, virological, and immunological correlations. Ann NY Acad Sci 1995;
753: 167-185.

6. Wiechers DO, Hubell SL. Late changes in the motor unit after acute poliomyelitis. Muscle

7. Peach PE. Overwork weakness with evidence of muscle damage in a patient with residual

8. Miller NE, Rao S, Byorsvik B, Mjos OD. High-density lipoprotein and physiological

9. Agre JC, Rodriguez AA, Sperling KB. Symptoms and clinical impressions of patients seen

of symptoms between Swedish and American post-polio individuals and assessment of lower

11. Windebank AJ, Ltchy WJ, Daube JR, Kurland LT, Codd MB, Iverson R. Late effects of

long-term follow-up study of patients with post-poliomyelitis neuromuscular symptoms. N


Footline: Strength in Polio Survivors


Suppliers

a. Hoggan Health Industries Inc., Draper, UT.

b. SYSTAT for Windows: Statistics, Ver. 7.0; Systat, Inc., Evanston, IL.
Footline: Strength in Polio Survivors