Progressive Resistance Exercise: Effect on Muscle Function and Anthropometry of a Select AIDS Population

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• Substantial body tissue wasting has been reported in acquired immune deficiency syndrome (AIDS) patients. The purpose of this investigation was to determine if progressive resistance exercise (PRE) would improve muscle function and increase body dimensions and mass in AIDS patients. The subjects were 24 male outpatient volunteers, status posttherapy for acute pneumocystis carinii pneumonia. Subjects were randomly assigned to control ($n=12$) or experimental ($n=12$) subsets. All subjects underwent muscle function testing on 12 variables of torque, force, power, and work; three variables of anthropometry were assessed. The experimental group engaged in PRE three times per week for six weeks. The control group did not exercise beyond their usual daily living activities. Both groups were retested at the end of six weeks. In comparison to the control group, the experimental group significantly increased in 13 of the 15 study variables. Thus, during the nonacute stage of AIDS, physiologic adaptation occurred that improved muscle function and increased body dimensions and mass.

KEY WORDS: Acquired immunodeficiency syndrome; Anthropometry; Exercise therapy

Substantial body tissue wasting has been reported in acquired immune deficiency syndrome (AIDS) patients.[1] Factors contributing to tissue wasting and general metabolic dysfunction include malabsorption, disruption of biochemical pathways, endocrine dysfunction, and toxic effects of chemotherapeutic agents.[2-4] AIDS patients also frequently have significant depletion of plasma volume and protein, and low intracellular potassium concentration,[5] factors that could affect muscle metabolism and function.

Other possible factors contributing to muscle atrophy and weakness are the nervous system disorders seen in AIDS patients, including demyelination, neuropathy, and neurosensory and neuromuscular disorders.[6-8] One or more of these nervous system conditions may affect muscle tissue anabolism and function. Myopathies have been reported in human immunodeficiency virus (HIV) patients;[9] thus, skeletal muscle may be directly involved in the spectrum of HIV disorders. Physical inactivity and psychogenic factors may also be major contributors to muscle atrophy, weakness, and fatigue.[10,11]

It is well established that progressive resistance exercise (PRE) results in compensatory muscle hypertrophy and improved muscle function in both diseased[12] and nondiseased[13] subjects. Whether muscle function and body dimensions and mass can be changed as an outcome of PRE in AIDS patients has not been determined. If muscle function can be improved and atrophy can be slowed, some of the secondary conditions that affect the physical functioning of AIDS patients could be reduced.

The primary purpose of our investigation was to determine if PRE would improve muscle function in AIDS patients. Secondarily, our purpose was to determine if changes in body dimensions and body mass would occur as an outcome of PRE in this population.

METHODS

Subjects

The subjects were 24 male outpatient volunteers undergoing treatment at the Institute for Immunological Disorders, Houston. They ranged in age from 23 to 46 years (mean 32 years). All had experienced and recovered from one episode of pneumocystis carinii pneumonia (PCP), with no other AIDS-defining opportunistic infection. The subjects were at least two weeks status posttherapy for acute PCP. They were following a protocol for azidothymidine (AZT), and they remained on AZT throughout the six weeks of the study. The Institute's Medical Review Board approved the study protocol.

After the subjects were informed of both the risks and possible benefits of study participation and had given written consent, they were randomly assigned to either control ($n=12$) or experimental ($n=12$) subsets. Then they underwent prestudy measurements of muscle function and anthropometry.

Muscle Function Testing

Measurements of muscle function were conducted on the OmniTron® computerized hydraulic resistance testing machine that is described elsewhere.[14,15] Three variables of muscle function were measured—maximum torque or force, maximum power, and total work. Torque or force represented the subject's maximum capacity to produce force, a quality of

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Abbreviations	
ET	Extension maximum torque
EF	Extension maximum force
EP	Extension maximum power
EW	Extension total work
FT	Flexion maximum torque
FF	Flexion maximum force
FP	Flexion maximum power
FW	Flexion total work
SSF	Sum of skinfolds
Girth	Sum of limb girths
BW	Body weight

muscle strength. The unit of torque, Newton-meter (Nm), described the rotational force for single-joint movement, whereas the unit of force, Newton (N), described the linear force produced by multijoint motions. Power, expressed in watts (W), reflected the subject's maximum capacity to exert force as a function of time, a product of contractile force and speed. Total work, expressed in joules (J), represented the capacity to apply force through distance repetitively, a quality of muscle endurance.

Reliability of the test instrument was determined by a test-retest method before and after each testing period using several denominations of dead weight standards under constant conditions of acceleration and distance. The resulting coefficients of correlation were >.99.

All subjects underwent muscle function testing of the following three muscle regions: (1) thighs and legs, (2) chest and arms, and (3) shoulder girdle and arms. They were tested at each region under two conditions: (1) five repetitions of high-resistance contractions, and (2) 25 repetitions of low-resistance contractions. The five-repetition, high-resistance effort assessed maximum torque or force and maximum power, whereas the 25-repetition test measured total work.

High resistance of the hydraulic testing instrument was regulated by a .025mm constant diameter orifice at the hydraulic fluid outflow valve. The magnitude of resistance was a function of the pressure exerted within the hydraulic cylinder by the contractile force and speed produced by the subject. Low resistance was regulated by a .12mm constant diameter orifice at the outflow valve, and observed the same hydraulic mechanics as high resistance.

Immediately before muscle function testing, the subjects performed stretching exercises and a five-minute warm-up on a leg-crank ergometer at low power output. This was followed by a practice trial of three repetitions at high-resistance effort before high-resistance testing and a ten-repetition practice trial at low resistance immediately before the low-resistance testing. After the first practice trial, subjects were tested on maximum effort for five repetitions against high resistance, and maximum torque or force and maximum power were determined. After a three-minute recovery period, subjects were tested on maximum effort for 25 repetitions against low resistance, and total work for the 25 repetitive contractions was determined.

The subject's range of motion for each muscle region and the test instrument's lever arm position for knee extension and flexion were standardized during prestudy testing and duplicated during poststudy testing. In order to determine intrasubject reliability, a repeat test trial of five repetitions was done to measure maximum torque during knee joint extension and flexion. The two test trials to determine intrasubject reliability were limited to the right knee joint, and they were performed during a single test session because additional repeat trials would create substantial fatigue in the subjects. From the prestudy and poststudy test-retest trials of maximum right knee joint torque, coefficients of reliability ranged from .90 to .92 for knee extension and from .85 to .88 for knee flexion.

The foregoing procedures were followed identically in the prestudy and poststudy test. All muscle function testing was performed by the same investigator to avoid intertester variability.

Anthropometry

Body weight was determined at the beginning of the pretest and posttest sessions. Girth measurements were taken using an anthropometric tape at two anatomic sites—the arm, halfway between the tip of the acromion and olecranon; and the thigh, halfway between the anterior superior iliac spine and the superior aspect of the patella. Skinfold thickness was measured by a skinfold caliper[b] at the following three anatomic sites: (1) the chest, halfway between the nipple and the anterior axillary line, a diagonal fold; (2) the abdomen, to the right of the umbilicus, a vertical fold; and (3) the anterior thigh, halfway between the anterior superior iliac spine and the superior aspect of the patella, a vertical fold.

PRE Training

The experimental group engaged in PRE three times per week for six weeks (18 exercise sessions). The control group did not exercise beyond their usual daily living activities. The Total Power[c] hydraulic resistance training unit was used for each exercise session; it is described elsewhere.[16] The resistance training unit provided bilateral movement and bidirectional, concentric contractions throughout the range of motion. The hydraulic resistance mechanism of the machine provided accommodating resistance that regulated the speed of movement.

The resistance load was uniformly increased throughout the six-week training period from one set of 15 repetitions on the unit's 1 (minimum) setting through three sets of ten repetitions on the unit's 6 (maximum) setting. Extrapolating from the experimental group's prestudy measurements at low and high resistance, table 1 presents an estimate of mean torque (Nm) and force (N) produced by the subjects at the minimum and maximum settings of the resistance unit during PRE training. During each exercise session, the subject was instructed to exert maximum muscular force against the exercise unit's lever arm throughout the range of motion in both directions of the movement. All exercise training sessions were supervised, and a maximum effort by the subjects was encouraged.

Data Analyses

Muscle function variables analyzed were maximum torque or force, maximum power, and total work for each muscle region and motion. Anthropometric variables included sum of skinfolds, sum of limb girths, and body weight. Test compar-

Table 1: Estimated Mean Torque and Force at Minimum and Maximum Resistance Settings During PRE Training

	Knee (Nm)		Chest-arms (N)		Shoulder-arms (N)	
	Extension	Flexion	Extension	Flexion	Extension	Flexion
Minimum setting	46	29	107	109	53	94
Maximum setting	218	153	626	501	242	492

ability between the two subsets through randomization of prestudy values of each of the variables was compared to verify that no biases were introduced by the subject assignment procedure. Prestudy mean values for each of the variables measured were subtracted from the poststudy mean values to reduce intersubject variability.

To determine if there were significant differences between the group means as a result of PRE, an independent samples t-test was performed. Besides determining if there was a difference between the two subsets, it was of interest to determine if there had been significant changes within each group from the baseline score. This was tested by an additional two-sided t-test of the incremental values within each group against a null hypothesis value of zero.

RESULTS

Table 2 presents the mean values for lower extremity muscle function of the two study groups. The between-group mean values were significantly different ($p<.01$) for all variables. Significant within-group differences ($p<.01$) were found between prestudy and poststudy means of the experimental subset on all variables of lower extremity muscle function, indicating improved performance. Significant within-group differences ($p<.05$) were evident between prestudy and poststudy means of the control subset on six of the 12 variables of muscle function, indicating a decline in performance on these six variables.

Table 3 presents the mean values of upper extremity muscle function of the two subsets. The between-group mean differences were significant ($p<.01$) for all variables except shoulder-arms extension power (EP). Significant within-group differences ($p<.05$) were found between prestudy and poststudy means for the experimental subset on all variables of upper extremity muscle function except shoulder-arms EP, and shoulder-arms flexion total work. Significant within-group differences ($p<.05$) were also found between prestudy and poststudy means of the control subset on seven of the 12 variables of muscle function, indicating a decline in performance on these seven variables.

Table 4 presents the mean values of anthropometry for the two subsets. The group mean differences were significant ($p<.01$) for all variables. Significant within-group differences ($p<.05$) were found between prestudy and poststudy means of the experimental subset for girth measurements and body weight, but not for the sum of skinfolds. Likewise, significant within-group differences ($p<.05$) were found between prestudy and poststudy means of the control subset for girth measurements and body weight (indicating a loss in limb and body mass), but not for the sum of skinfolds.

The large number of variables with a resultant large number of hypotheses' tests raised the possibility that certain differences that are considered to be significant at a nominal Type I error rate could have arisen due to chance variation alone. To guard against this possibility, two strategies were employed for the analysis of the differences between the two groups in incremental strength and size measures.

The first was to use the Bonferroni method of dividing the

Table 2: Lower Extremity Muscle Function of AIDS Patients

	Control group ($n=12$)				Experimental group ($n=12$)						
Variable	Prestudy mean ±SEM	Poststudy mean ±SEM	Mean difference	t statistic	Prestudy mean ±SEM	Poststudy mean ±SEM	Mean difference	t statistic	Treatment difference*	t statistic	Significance of t
Right knee											
ET(Nm)	102.3± 5.9	88.8± 6.1	−13.5	−2.69†	109.5± 5.3	130.5± 6.27	21.0	3.29‡	34.5	4.24	0.000
EP(W)	99.7± 8.4	84.5± 8.3	−15.2	−1.94	106.8±10.4	141.5±10.3	34.7	4.10‡	49.9	4.33	0.000
EW(J)	264.2±16.6	236.4±19.2	−27.8	−1.68	271.9±17.9	341.1±12.7	69.2	3.97‡	97.0	4.04	0.001
FT(Nm)	74.6±19.7	66.9± 6.2	−7.7	−2.14	77.0± 4.8	103.1± 5.1	26.1	4.94‖	33.8	5.29	0.000
FP(W)	75.6± 9.8	63.0± 7.4	−12.6	−2.27†	80.5± 8.4	127.2± 9.6	46.7	4.83‖	59.3	5.32	0.000
FW(J)	290.1±26.7	260.3±25.9	−29.8	−1.01	295.5±31.1	405.9±28.9	110.4	4.29‡	140.2	3.58	0.002
Left knee											
ET(Nm)	96.4± 6.7	83.6±21.0	−12.8	−2.71†	108.0± 4.9	126.8± 5.6	18.8	4.06‡	31.6	4.78	0.000
EP(W)	91.3± 9.9	79.2± 7.9	−12.1	−1.53	108.5± 7.3	142.1± 8.5	33.6	4.23‡	45.7	4.08	0.000
EW(J)	271.5±16.3	238.1±16.6	−33.4	−2.37†	277.6±21.9	343.0±15.2	65.4	3.29‡	98.8	4.05	0.001
FT(Nm)	77.4± 5.6	65.2± 6.4	−12.2	−2.45†	76.2± 4.2	95.4± 6.2	19.2	4.99‖	31.4	5.00	0.000
FP(W)	75.7± 8.6	60.9± 8.2	−14.8	−2.28†	80.4± 7.1	114.3±11.7	33.9	4.58‖	48.7	4.94	0.000
FW(J)	288.1±33.4	243.4±18.7	−44.7	−1.90	300.4±33.1	395.1±24.8	94.7	4.43‖	139.4	4.39	0.000

*The differential between the control group and experimental group mean difference † difference significant at $p<.05$; ‡ difference significant at $p<.01$; ‖ difference significant at $p<.001$

Table 3: Upper Extremity Muscle Function of AIDS Patients

Variable	Control group ($n=12$) Prestudy mean ± SEM	Post-study mean ± SEM	Mean difference	t statistic	Experimental group ($n=12$) Prestudy mean ± SEM	Post-study mean ± SEM	Mean difference	t statistic	Treatment difference*	t statistic	Significance of t
Chest-arms											
EF(N)	594.3 ± 25.2	476.7 ± 48.3	−117.6	−3.00†	625.6 ± 38.2	748.9 ± 32.6	123.3	4.92‖	240.9	5.17	0.000
EP(W)	117.6 ± 7.2	94.2 ± 9.6	− 23.4	−2.31†	126.6 ± 12.0	169.8 ± 12.8	43.2	4.73‖	66.6	4.88	0.000
EW(J)	809.1 ± 78.5	647.7 ± 64.9	−161.4	−2.21†	844.3 ± 66.2	1022.3 ± 68.6	178.0	3.12†	339.4	3.66	0.001
FF(N)	498.5 ± 29.2	403.3 ± 48.1	− 95.2	−2.65†	500.7 ± 18.3	590.4 ± 19.7	89.7	4.47‖	184.9	4.49	0.000
FP(W)	94.1 ± 8.7	79.5 ± 10.4	− 14.6	−2.16†	97.1 ± 6.3	132.0 ± 16.4	34.9	2.75†	49.5	3.44	0.002
FW(J)	773.4 ± 48.7	688.5 ± 77.6	− 84.9	−1.35	854.1 ± 70.3	1059.8 ± 57.1	205.7	3.69‡	290.6	3.46	0.002
Shoulder-arms											
EF(N)	218.3 ± 9.05	176.3 ± 18.2	− 42.0	−2.05	241.6 ± 13.6	275.6 ± 15.6	34.0	2.87†	76.2	3.22	0.004
EP(W)	51.5 ± 4.10	42.1 ± 4.5	− 9.4	−2.12	68.3 ± 14.3	76.8 ± 7.3	8.5	0.77	17.9	1.50	0.148
EW(J)	404.4 ± 30.4	296.4 ± 32.0	−108.0	−3.73‡	448.8 ± 38.9	547.6 ± 43.3	98.8	3.49‡	196.8	5.11	0.000
FF(N)	433.3 ± 25.3	357.6 ± 40.7	− 75.4	−1.87	491.5 ± 23.7	542.6 ± 19.6	51.1	2.92†	126.5	2.88	0.009
FP(W)	139.0 ± 12.0	119.1 ± 11.9	− 19.9	−1.66	174.1 ± 13.8	202.7 ± 13.8	28.6	3.00†	48.5	3.16	0.005
FW(J)	807.9 ± 64.2	617.7 ± 70.4	−190.2	−4.44‖	1048.3 ± 102.3	1211.4 ± 115.3	163.1	1.80	353.3	3.52	0.002

*The differential between the control group and experimental group mean difference; †difference significant at $p<.05$; ‡difference significant at $p<.01$; ‖difference significant at $p<.001$

nominal Type I error chosen for significance, ie, $p=.05$, by the number of tests being made. This was done on a variable cluster basis, ie, separately for the right knee, left knee, chest-arms, and shoulder-arms muscle groups as well as for the anthropometric measures. The first four of these clusters involved six variables each. Therefore, for the muscle groups a requirement of $p=.05/6$ or .008 was selected for significance. Likewise, for the anthropometric cluster where three variables re involved, a criterion of $p=.05/3$ or .0016 was used. If ...bles 2, 3, and 4 were examined with the more stringent criteria, all the differences between the 2 groups would still be considered significant, except for shoulder-arms EP and shoulder-arms flexion force. For those two variables, the treatment group did not exhibit a significant improvement over the control group.

As a further assurance against specious significance, a Hotelling T^2 test[17] was performed for each variable grouping. The results of this test are shown in table 5. Again, there was a highly significant difference between the exercise group and the control group.

In summary, at the end of the six weeks, the experimental subset demonstrated an increase in all but two variables of muscle function, body dimensions and mass. Also, in the same time, all variables declined in the control group. However, the differences within groups were not always significant.

DISCUSSION

We found that there was a significant difference between the control and experimental subsets of the study population in virtually all variables of muscle function, body dimensions, and mass as an outcome of chronic muscle training. Thus, during the nonacute stage of the disease, physiologic adaptation occurred in an HIV-infected population that underwent PRE. We also observed a trend of decline in all variables of muscle function, body dimensions, and mass within the control subset.

We did not find that PRE training exacerbated the disease process among the experimental subjects during the study period. However, we speculate that during the acute stage of opportunistic infection, exercise training programs will need to be modified to include mild exercise and energy conservation techniques.

The mechanism by which muscle function was sustained or improved and body dimensions and mass were retained or increased after PRE has not been elucidated by the study design. Still, it would be useful to comment on adaptation mechanisms in our study group.

HIV infection has been reported to involve both the central and peripheral nervous systems.[10,18] Muscle biopsies of HIV-infected patients have shown the presence of retrovirus parti-

Table 4: Anthropometry of AIDS Patients

Variable	Control group ($n=12$) Prestudy mean ± SEM	Post-study mean ± SEM	Mean difference	t statistic	Experimental group ($n=12$) Prestudy mean ± SEM	Post-study mean ± SEM	Mean difference	t statistic	Treatment difference*	t statistic	Significance of t
SSF(mm)	61.9 ± 5.52	57.0 ± 5.01	−4.9	−2.01	65.4 ± 3.77	70.5 ± 4.23	5.1	2.02	10.0	2.85	0.009
Girth (cm)	78.5 ± 1.95	76.3 ± 1.78	−2.2	−3.01†	80.2 ± 1.48	83.7 ± 1.66	3.5	5.67‡	5.7	5.97	0.003
(kg)	69.3 ± 2.55	67.4 ± 2.72	−1.9	−2.50†	70.8 ± 1.72	72.5 ± 2.15	1.7	2.28†	3.6	3.38	0.000

...ne differential between the control group and experimental group mean difference; †difference significant at $p<.05$; ‡difference significant at $p<.001$

Table 5: Multivariate Comparisons

Vector of variables	Hotelling T^2 statistic	*df* (hypothesis, error)	Significance of T^2
Right knee muscle group (ET,EP,EW,FT,FP,FW)	8.439	(6,17)	0.000
Left knee muscle group (ET,EP,EW,FT,FP,FW)	4.997	(6,17)	0.004
Chest-arms muscle group (EF,EP,EW,FF,FP,FW)	5.011	(6,17)	0.004
Shoulder-arms muscle group (EF,EP,EW,FF,FP,FW)	4.493	(6,17)	0.007
Anthropometric measures	11.27	(3,20)	0.000

cles; demyelination and inflammation have been observed in peripheral nerve specimens.[10,11] Either one or both of these conditions could contribute to the muscular weakness and atrophy that has been associated with HIV infection. Whether our study population had HIV involvement of nerve and muscle is not known. Nevertheless, regardless of the degree of HIV involvement in the skeletal muscles and nervous systems of the experimental subset, resistance exercise appeared to evoke a response of the adaptation pathways that activate protein synthesis of muscle tissue and/or neural factors that produce an increase in skeletal muscle function.

Our study has demonstrated that PRE resulted in improved muscle function and anthropometry of the experimental subset as compared to the control subset. Therefore, we speculate that similar effects would be obtained in HIV-infected and AIDS-related-complex patients who have not had an opportunistic infection.

Because it appears that the disease progression does not disallow physiologic adaptation, early intervention with PRE may slow the rate of muscle atrophy that is common in this patient population. Considering the debilitating effect that prolonged bedrest or inactivity has on physical function and the concomitant decline in quality of life characteristic of the AIDS patient, it is important to begin exercise therapy as soon as the patient's clinical status will allow. However given the spectrum of HIV disorders, it is also important to gauge the efficacy of exercise therapy throughout the disease process on an individual basis.

Future investigations are needed to determine the long-term effect that PRE has on muscle function and anthropometry of AIDS patients. Meanwhile, it would seem prudent for health care professionals to establish carefully monitored PRE training programs as a potentially valuable therapeutic approach in the management of HIV-infected individuals.

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