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THE IMPORTANCE OF AGE EFFECTS ON PERFORMANCE IN THE ASSESSMENT OF CLINICAL TRIALS*

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INTRODUCTION

DURING the past decade, a large battery of performance tests called the Quantitative Examination of Neurological Function (QENF) has been assembled [1–4]. A summary description of the tests in the battery has been published [4, 5]. Recently, the test battery has been used to evaluate clinical drug trials [5–7].

The present study, designed to objectively evaluate certain measurement procedures, is concerned with the effects of age and whether these effects must be considered in selecting normal control groups for evaluating the performance of patients. In recent therapeutic trials [5, 6], we have expressed the performance of patients in terms of a percentage of normal function because it is the physician's goal to return the patient to his pre-disease functional level. Thus, it is of far more importance that a patient's neurological function approach normal than it is that he double or triple some earlier functional level.

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We have been concerned with the consequences of expressing the patient's performance as a percentage of normal function. The problem arises in the definition of normal function. Researchers have considered both young adult control groups (e.g. [8]) and control groups more closely matched to patients (e.g. [5]). The primary advantage of using a young adult normal control group is that it is relatively easy to recruit such subjects for evaluation, especially when the research is conducted in a university environment. The major disadvantage is that such a control group may distort the results of a clinical trial. For example, the performance level of an elderly control group may be 75 per cent that of a group of young adults. Although elderly patients in a therapeutic trial may have improved from 40 to 70 per cent of the normal function of young adults, they in fact have improved from 54 to 94 per cent of the normal function for their age group. Obviously, different conclusions might be reached with regard to the efficacy of the therapy depending upon which normal group is used as the control group.

It appears that a matched control group is superior to a young adult control group. However, there are some important disadvantages to using a matched control group. It is difficult to define what constitutes a good match; to obtain volunteers for evaluation, especially males from 25 to 65 yr of age; and to find truly asymptomatic volunteers, especially volunteers over 45 yr of age.

Age effects appear to be a most important criterion for matching patients to normal controls. However, an evaluation of the effects of age on performance in a large, diversified battery of tests like the QENF has not been reported. Botwinick [9] has recently reviewed the literature on the psychology of aging from 1963 to 1968. His bibliographical search disclosed nearly 2000 references. No attempt will be made here to review this literature. A brief review of age effects and their relationship to the QENF has been made [3].

In the present study, the effects of age on performance are limited to an investigation of all the QENF tests using three normal control groups: a young adult normal subject group, a group matched to multiple sclerosis patients and a group matched to parkinsonian patients. The performance of each matched control group and each patient group (a parkinsonian group and a multiple sclerosis group) is normalized to the performance of the young adult normal group. In addition, the performance of each patient group is normalized to that of its matched control group. From these results the relative effects of using different types of control groups in the QENF are assessed.

METHODS

Twenty asymptomatic right-handed male and twenty asymptomatic right-handed female University of Michigan undergraduate students, 18–21 yr of age (mean=19.5 yr, standard deviation=1.1 yr), volunteered to participate in the study. In addition, 5 male and 5 female patients having multiple sclerosis (age: mean=35.1 yr, standard deviation=7.9 yr) and their normal spouses (age: mean=37.0 yr, standard deviation=7.2 yr), 5 male and 5 female parkinsonian patients (age: mean=65.6 yr, standard deviation=6.2 yr) and their normal spouses (age: mean=60.9 yr, standard deviation

= 10.8 yr) were asked by their neurologist to perform as subjects in these experiments. All subjects were told that their assistance would help our medical research program.

The selection process of patients was based on the following criteria: (1) patients must be right-handed; (2) patients must have a tremor characterized as slight, mild, or moderate in at least one upper extremity; (3) however poorly, the patients must be able to drink from a glass, use a fork, cut meat, button a garment when the buttons are visible and write; (4) multiple sclerosis patients must be 25–45 yr of age and parkinsonian patients must be 50–75 yr of age; and (5) parkinsonian patients must be able to walk 10 steps with assistance and, as often as possible, the multiple sclerosis patients must also be able to meet this requirement. Requirements for selecting older normal subjects were that they be in the same age range as their afflicted spouses, that they be neurologically and physically normal and right-handed.

Neither the patients, who were outpatients at the University Hospital, nor the older adult normal subjects were paid a nominal fee for participating in the study. However, the university students were paid to volunteer their services. No subject was informed that he might receive special pay contingent on performance. Subjects were admitted to the study after completing a telephone questionnaire and an abbreviated neurological examination and medical history.

Three groups of subjects were selected as normal controls: a young adult control group consisting of the 40 university students, a matched control group for the parkinsonian patients consisting of the 10 spouses* of the parkinsonian patients, and a matched control group for the multiple sclerosis patients consisting of the 10 spouses* of the multiple sclerosis patients. The matched control groups were matched to the patient groups not only with respect to age but also to sex, education and socioeconomic background. The 10 parkinsonian patients and the 10 multiple sclerosis patients formed the remaining two groups used in this study.

The general experimental procedures were standardized. All subjects were instructed by the attending physician and the paramedical personnel to perform in all tests in the QENF as well as they could.

RESULTS

Age effects

Results of an analysis of variance among the three subject groups and a simple linear regression analysis with age as the independent variable for the 60 normal subjects are shown in Table 1. There are few differences in results between the significance level of the F value denoting differences among the three groups in the analysis of variance and the significance level of the t value denoting a slope different from zero in the regression analysis. Differences, where they exist, appear to be technical, i.e. the differences do not appear to have clinical significance.

The data were also analyzed with male and female subjects considered separately (not shown). The few differences found with the sexes considered separately and together appear to be technical. Trends for all tests were similar whether the sexes were considered separately or together.

*A few exceptions existed: one patient's brother, one patient's sister, and the parents of a MS patient were substituted when normal spouses were not available.

TABLE 1. A CROSS-SECTIONAL STUDY INVOLVING THE EFFECTS OF AGE ON PERFORMANCE IN THE QENF[1] ADMINISTERED TO 30 NORMAL MALES AND 30 NORMAL FEMALES (AGE RANGE: 18–74 YR OLD)

				Analysis of variance[3]		Simple regression analysis[2]			
Test	Mean 1	Mean 2	Mean 3	$F_{(2,58)}$	Significantly different groups[4]	r	Score=a+b (age) a	b	$\lvert t_{(59)} \rvert$
CQNE, vision									
Corrected distance vision	96.7	98.6	94.5	1.30		–.15	98.2	–.055	1.18
Uncorrected distance vision	79.2	89.6	73.8	1.01		–.17	212.7	–2.427	1.32
Near and distance vision	98.3	99.3	96.1	2.71		–.24	99.6	–.049	1.90
Pinhole vision	92.0	91.2	91.7	0.02		–.10	93.8	–.067	0.76
CQNE, upper extremities									
Grip strength, 1–D	75.7	88.7	69.7	1.34		–.15	84.4	–.255	1.18
Grip strength, 1–N	69.3	80.5	60.5	1.61		–.19	78.4	–.298	1.50
Grip strength, 2	76.3	80.3	65.0	1.19		–.26	86.2	–.379	2.05*
Wrist dorsiflexion strength	41.9	46.8	37.5	1.29		–.17	46.0	–.136	1.33
Shoulder abduction strength	21.9	26.7	19.6	2.26		–.13	24.3	–.065	1.04
Hole steadiness, supported	2.1	2.1	2.8	14.93***	3 1 2	.55	1.7	.016	5.03***
Hole steadiness, unsupported–D	7.1	6.1	8.1	1.87		.17	6.4	.025	1.33
Hole steadiness, unsupported–N	7.7	6.3	8.1	1.70		.04	7.4	.006	0.33
Force steadiness, supported–D	2.9	3.5	5.3	10.36***	3 2 1	.49	1.8	.052	4.31***
Force steadiness, supported–N	3.1	3.3	5.4	7.76***	3 2 1	.38	2.3	.041	3.09**
Force steadiness, unsupported	7.8	9.2	9.9	2.47		.15	7.5	.028	1.14
Resting tremor–D	0.5	0.7	1.1	12.54***	3 2 1	.54	0.2	.013	4.83***
Resting tremor*N	0.5	0.6	0.9	4.43*	3 2 1	.26	0.4	.006	2.03*
Sustention tremor	2.8	2.2	3.2	2.02		.03	2.7	.002	0.24
Static intention tremor–D	1.6	1.4	1.8	0.46		.05	1.5	.003	0.39
Static intention tremor–N	1.8	1.6	2.4	1.80		.12	1.6	.008	0.95
Simple reaction time	8.3	8.4	9.8	6.05**	3 2 1	.47	7.5	.037	4.10***
Hand speed, 1–D	65.4	65.1	60.6	1.79		–.30	68.5	–.135	2.40*
Hand speed, 1–N	58.0	57.9	57.3	0.03		–.11	59.6	–.057	0.82
Hand speed, 2–D	71.0	69.9	65.6	2.05		–.35	74.7	–.162	2.82**

TABLE 1. *Continued*

Hand speed, 2–N	63.4	64.2	61.1	0.54		–.16	65.3	–.072	1.27
Hand coordination, 1–D	37.0	36.8	32.0	4.36*	1 2 3	–.39	39.7	–.121	3.19**
Hand coordination, 1–N	31.1	29.9	30.2	0.46		–.16	31.8	–.038	1.25
Hand coordination errors, 1–D	1.1	0.8	1.0	0.13		–.00	1.0	–.000	0.01
Hand coordination errors, 1–N	1.6	0.8	0.2	3.91*	1 2 3	–.32	2.1	–.031	2.57*
Hand coordination, 2	10.4	10.0	9.3	5.72**	1 2 3	–.41	11.0	–.027	3.47***
Hand coordination errors, 2	5.6	3.7	2.5	7.56**	1 2 3	–.44	6.8	–.071	3.74***
Rotary pursuit, 30 rpm–D	59.9	51.3	46.8	4.27	1 2 3	–.36	65.9	–.328	2.98**
Rotary pursuit, 30 rpm–N	52.4	42.2	37.5	5.85**	1 2 3	–.44	59.9	–.398	3.75***
Rotary pursuit, 60 rpm–D	13.6	8.7	9.1	2.42		–.31	16.4	–.148	2.45*
Rotary pursuit, 60 rpm–N	9.0	5.5	8.8	1.11		–.13	9.9	–.052	0.97
Purdue pegboard	15.2	15.0	13.5	4.52*	1 2 3	–.41	16.0	–.040	3.44**
Large peg rotation	11.5	11.7	13.0	1.62		.23	10.8	.035	1.82
Small peg rotation	11.9	11.3	12.4	0.66		.06	11.6	.008	0.45
Pencil rotation–D	14.9	14.0	12.8	5.41**	1 2 3	–.46	16.0	–.054	3.93***
Pencil rotation–N	12.4	12.1	11.3	1.85		–.34	13.2	–.036	2.75**
Pencil rotation errors–D	0.1	0.0	0.3	2.42		.22	–0.0	.004	1.72
Pencil rotation errors–N	0.5	0.2	0.2	1.90		–.23	0.7	–.009	1.77
Grip strength fatigue–D	85.9	83.8	79.4	1.12		–.22	89.5	–.170	1.73
Grip strength fatigue–N	78.4	80.3	86.9	2.03		–.26	74.4	.195	2.07*
Hand speed fatigue	85.3	81.9	86.5	1.12		.06	84.1	.027	0.46
Vibration sense of finger, 1–D	1.4	2.0	3.1	9.48***	3 2 1	.64	0.3	.050	6.36***
Vibration sense of finger, 1–N	1.2	1.5	2.7	8.57***	3 2 1	.60	0.2	.042	5.65***
Vibration sense of finger, 2	0.4	1.1	1.5	7.37**	3 2 1	.54	–0.3	.032	4.94***
Two-point discrimination	3.3	3.8	4.3	18.14***	3 2 1	.58	2.9	.022	5.47***
CQNE, lower extremities									
Foot dorsiflexion strength	64.3	68.3	57.2	1.27		–.17	68.6	–.166	1.31
Hip flexion strength	26.9	29.5	21.9	2.07		–.26	30.6	–.138	2.05*
Foot speed–D	53.1	51.5	51.0	0.33		–.16	54.9	–.080	1.21

[*Table 1 continued on next page*]

TABLE 1. *Continued*

Test	Mean 1	Mean 2	Mean 3	Analysis of variance[3] $F_{(2,58)}$	Significantly different groups[4]	Simple regression analysis[2] r	Score = a + b (age) a	b	$\lvert t_{(59)} \rvert$
Foot speed–N	50.7	43.0	46.6	3.82*	1 3 2	–.29	53.2	–.152	2.30*
Foot coordination	6.3	6.3	6.0	0.67		–.13	6.4	–.006	1.02
Foot coordination errors–D	4.7	2.6	2.0	3.21*	1 2 3	–.27	5.6	–.059	2.16*
Foot coordination errors–N	4.4	1.8	3.3	3.93*	1 3 2	–.23	5.0	–.039	1.78
Tandem gait with supports	3.3	2.9	2.3	22.65***	1 2 3	–.66	3.8	–.024	6.75***
Tandem gait without supports	3.2	2.8	2.2	18.85***	1 2 3	–.62	3.7	–.023	6.03***
Foot speed fatigue	81.8	79.3	80.4	0.24		–.04	82.0	–.029	.34
Vibration sense of toe, 1	3.6	5.7	26.4	15.26***	3 2 1	.68	–9.6	.592	7.04***
Vibration sense of toe, 2	4.8	9.3	18.0	7.94***	3 2 1	.57	–3.0	.365	5.34***
SADLE									
Putting on a shirt	7.4	8.1	7.9	0.45		.13	7.1	.017	0.96
Managing three visible buttons	11.7	10.5	12.0	1.86		.04	11.4	.005	0.34
Zipping a garment	2.1	2.3	3.1	17.74***	3 2 1	.64	1.7	.022	6.26***
Putting on gloves	5.9	7.4	7.1	3.10		.27	5.3	.034	2.10*
Dialing a telephone	8.7	9.4	10.3	14.39***	3 2 1	.64	7.8	.042	6.41***
Tying a bow	6.4	5.8	6.1	0.94		–.42	6.3	–.003	0.32
Manipulating safety pins	5.0	4.5	4.9	1.31		–.10	5.1	–.005	0.76
Picking up coins	5.2	5.7	6.3	5.25**	3 2 1	.42	4.6	.028	3.52***
Threading a needle	3.3	3.1	3.3	0.07		.02	3.2	.001	0.12
Unwrapping a Band-Aid	9.6	12.1	14.2	9.56***	3 2 1	.48	7.7	.105	4.16***
Squeezing toothpaste	2.8	2.8	4.0	12.83***	3 1 2	.55	2.2	.028	5.06***
Cutting with a knife	6.7	6.2	8.3	6.09**	3 1 2	.32	5.9	.031	2.61*
Using a fork	1.4	1.5	1.7	3.57*	3 2 1	.33	1.3	.006	2.70**
NPE									
Test anxiety questionnaire	27.0	32.6	28.7	1.85		.10	26.7	.052	0.78

TABLE 1. *Continued*

Counting	70.4	68.0	61.7	1.25		−.28	76.3	−.266	2.21*
Similarities	19.7	18.3	16.9	4.37*	1 2 3	−.33	20.8	−.060	2.70**
Digits forward	7.3	7.0	6.4	2.13		−.25	7.6	0.018	1.94
Digits backward	5.6	4.4	4.1	8.48***	1 2 3	−.48	6.2	−.038	4.12***

[1]Scores for the D (Dominant) and N (Nondominant) body sides of normal subjects are not combined when the difference in means is at least 10 per cent and $p \leq 0.05$. All subjects declared themselves right-handed. For test units, refer to Table 1 in [3]. Abbreviated terms include: QENF, Quantitative Examination of Neurological Function; CQNE, Clinical Quantitative Neurological Examination; SADLE, Simulated Activities of Daily Living Examination; NPE, Neuro-Psychological Examination.

[2]r denotes the Pearson product-moment correlation coefficient.

[3]The 60 normals are divided into three groups having equal numbers of males and females as follows: Group 1: 40 young adult normals, 18–21 yr old; Group 2: 10 older adult normals, 25–48 yr old; Group 3: 10 oldest adult normals, 44–74 yr old.

[4]The Duncan New Multiple Range Test is used to determine which groups are significantly different at the 0.05 level. Any two groups not underscored by the same line are significantly different. Any two groups underscored by the same line are not significantly different.

*$p \leq 0.05$.

**$p \leq 0.01$.

***$p \leq 0.001$.

TABLE 2. PERFORMANCE OF PATIENTS AND MATCHED NORMALS IN THE QENF[1] EXPRESSED AS A PERCENTAGE OF YOUNG ADULT NORMAL FUNCTION

Test	Young adult normal function[2]						Percentage of young adult normal function							
	20 Males		20 Males + 20 Females		20 Females		10 Matched normals for MS patients		10 Matched normals for PD patients		10 MS patients		10 PD patients	
	Mean	±2SD	Mean	±2SD	Mean	±2SD	%	SD	%	SD	%	SD	%	SD
CQNE, vision														
Corrected near vision			100.0	0.0			100.0	0.0	97.8	7.0	71.8	29.7	81.8	25.6
Corrected distance vision			96.7	11.1			102.0	2.4	97.7	9.1	75.9	19.4	92.3	13.3
Near and distance vision			98.3	5.5			101.1	1.2	97.8	5.6	73.8	20.8	87.0	18.2
Pinhole vision			92.0	22.3			99.2	15.0	100.0	8.5	84.3	18.2	95.2	11.3
CQNE, upper extremities														
Grip strength, 2	94.9	31.7			57.8	20.4	105.0	11.2	83.3	24.2	95.1	48.6	67.2	24.5
Wrist dorsiflexion strength	52.4	12.5			31.4	10.1	111.0	14.9	87.4	19.8	80.0	38.4	76.2	29.2
Shoulder abduction strength	28.1	8.8			15.7	4.4	120.0	20.4	88.0	18.4	84.9	44.4	78.3	39.4
Hole steadiness, supported			2.1	0.5			102.0	6.6	79.8	22.0	69.2	19.6	47.7	23.6
Hole steadiness, unsupported-D			7.1	4.1			120.0	19.5	105.4	44.7	55.4	18.8	53.3	21.6
Hole steadiness, unsupported-N			7.7	4.9			128.0	30.0	108.5	42.3	62.3	25.8	58.9	30.3
Force steadiness, supported-D			2.9	2.6			96.0	39.6	68.7	43.4	56.6	29.3	57.4	35.5
Force steadiness, supported-N			3.1	3.1			119.0	54.7	69.0	41.1	100.0	60.8	73.0	62.8
Force steadiness, unsupported	9.4	4.2			6.1	3.9	92.9	25.0	82.7	23.5	84.5	44.3	67.9	37.3
Resting tremor–D	0.6	0.5			0.3	0.4	83.2	45.0	51.4	23.2	102.0	91.7	49.7	42.7
Resting tremor–N	0.7	0.6			0.4	0.4	90.6	30.0	90.4	70.4	128.0	99.4	49.1	42.4
Sustention tremor	3.4	1.7			2.1	1.2	130.0	26.8	107.0	42.4	92.7	36.0	56.2	32.9
Static intention tremor–D	1.9	1.8			1.3	1.2	143.0	81.0	99.6	23.7	99.2	57.4	56.3	30.1
Static intention tremor–N	2.1	2.5			1.5	1.1	161.0	155.0	96.3	45.9	103.4	52.7	51.8	31.1
Simple reaction time			8.3	2.3			100.5	12.4	86.8	5.2	65.6	14.0	76.7	17.6
Hand speed, 1–D			65.4	13.7			99.5	10.8	92.6	13.8	49.2	17.2	57.5	17.3
Hand speed, 1–N			58.0	17.5			99.7	9.2	98.7	20.1	49.8	19.8	56.8	20.6
Hand speed, 2–D			71.0	13.7			98.5	9.4	92.4	15.0	61.0	15.4	76.6	12.7
Hand speed, 2–N			63.4	15.1			101.0	9.9	96.3	10.4	63.5	11.2	80.0	17.7
Hand coordination, 1–D			37.0	9.8			99.5	12.9	86.5	12.8	39.5	14.5	59.7	12.0
Hand coordination, 1–N			31.1	7.7			96.3	13.1	97.3	12.2	50.5	19.1	69.6	12.0
Hand coordination errors, 1–D			1.1	3.1			142.0	74.0	126.0	75.1	173.0	60.9	180.0	66.7
Hand coordination errors, 1–N	2.3	3.8			1.0	2.8	190.0	108.0	286.0	143.0	283.0	151.0	293.0	174.0
Hand coordination, 2			10.4	1.8			96.1	10.9	89.0	9.8	49.6	13.2	61.5	10.6

TABLE 2. *Continued*

Hand coordination errors, 2	6.5	5.7			4.6	4.4	205.0	136.0	277.0	162.0	255.0	183.0	362.0	204.0
Rotary pursuit, 30 rpm–D			52.4	27.7			87.1	24.6	78.0	21.7	12.7	10.5	27.3	15.9
Rotary pursuit, 30 rpm–N	65.6	26.1			54.2	28.2	80.5	22.7	71.6	28.4	18.0	11.9	49.6	26.2
Rotary pursuit, 60 rpm–D	17.7	14.0			9.5	15.5	68.2	53.1	63.7	41.9	6.4	6.0	18.9	19.4
Rotary pursuit, 60 rpm–N	12.4	12.0			5.6	7.0	70.0	84.8	79.2	77.5	15.5	25.2	18.1	16.6
Purdue pegboard			15.2	3.0			98.6	9.4	89.4	11.4	33.3	18.4	60.3	10.3
Large peg rotation	10.4	2.8			12.6	5.0	101.0	20.0	91.2	16.4	49.6	23.5	65.5	13.3
Small peg rotation			11.9	4.4			108.0	20.0	96.4	10.5	48.5	20.4	67.8	10.0
Pencil rotation–D	15.5	2.6			14.3	2.9	93.9	6.7	86.1	19.7	43.6	8.5	48.6	15.4
Pencil rotation–N	13.4	2.8			11.5	2.5	97.8	11.5	90.7	17.9	44.7	12.1	48.5	15.4
Grip strength fatigue–D			85.9	26.5			104.0	14.0	110.0	15.4	118.0	26.6	118.0	21.5
Grip strength fatigue-N			78.4	25.2			99.0	14.0	91.1	9.5	107.0	23.6	98.6	16.8
Hand speed fatigue			85.3	14.4			105.0	7.5	99.5	9.7	102.0	17.6	101.0	11.0
Touch sense of hand			6.0	0.0			100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0
Vibration sense of finger, 1–D			1.4	1.3			89.6	40.8	64.3	35.9	52.9	51.4	58.7	23.3
Vibration sense of finger, 1–N			1.2	1.1			91.0	34.3	67.2	42.3	55.4	53.7	63.7	37.0
Vibration sense of finger, 2			0.4	0.6			114.0	117.0	81.0	116.0	48.0	44.2	101.0	114.3
Position sense			1.0	0.0			100.0	0.0	100.0	0.0	97.5	7.9	100.0	0.0
Two-point discrimination			3.2	0.9			88.0	11.2	77.9	10.9	57.8	22.8	69.0	11.0
CQNE, lower extremities														
Foot dorsiflexion strength	75.2	19.2			53.3	17.1	105.0	23.0	87.7	14.7	34.4	41.0	80.5	24.6
Hip flexion strength	33.1	10.1			20.7	7.3	107.0	28.4	80.9	17.8	20.2	27.7	60.3	32.2
Foot speed	56.5	13.1			47.3	13.4	91.4	12.6	93.8	9.5	25.5	21.0	70.8	21.3
Foot coordination			6.3	1.5			101.2	6.7	96.0	10.5	23.2	21.6	63.6	20.6
Foot coordination errors–D			4.6	6.8			398.0	149.0	339.0	167.0	418.0	443.0	426.0	123.0
Foot coordination errors–N			4.4	5.9			332.0	147.0	247.0	174.0	503.0	364.0	325.0	159.0
Two leg standing, eyes open			30.0	0.0			100.0	0.0	100.0	0.0	55.0	48.5	100.0	0.0
One leg standing, eyes open			30.0	0.0			100.0	0.0	84.0	30.8	4.5	9.6	24.5	34.6
Two leg standing, eyes closed			30.0	0.0			100.0	0.0	100.0	0.0	21.7	41.6	100.0	0.0
One leg standing, eyes closed			30.0	0.0			91.8	18.7	36.8	28.8	0.0	0.0	6.5	10.5
Tandem gait with supports			3.3	0.8			87.6	16.1	68.7	17.2	19.6	18.1	46.9	9.8
Tandem gait without supports			3.2	0.9			87.5	17.1	69.1	16.9	7.4	15.8	44.1	13.2
Foot speed fatigue			81.8	19.4			106.0	19.0	103.0	11.4	102.0	71.1	98.4	16.0
Touch sense of toe			5.9	0.5			96.6	8.2	90.7	20.4	79.7	31.2	80.5	20.9

[*Table 2 continued on next page*]

TABLE 2. *Continued*

Test	Young adult normal function[2]						Percentage of young adult normal function							
	20 Males		20 Males+ 20 Females		20 Females		10 Matched normals for MS patients		10 Matched normals for PD patients		10 MS patients		10 PD patients	
	Mean	±2SD	Mean	±2SD	Mean	±2SD	%	SD	%	SD	%	SD	%	SD
Vibration sense of toe, 1			3.6	4.9			113.0	91.4	39.2	48.3	11.4	22.2	13.0	19.0
Vibration sense of toe, 2			4.8	9.4			190.0	192.0	135.0	192.0	15.4	16.0	38.8	31.1
Position sense			1.0	0.0			100.0	0.0	100.0	0.0	72.5	24.9	97.5	5.3
SADLE														
Putting on a shirt			7.4	3.9			105.0	36.4	97.0	17.5	41.4	25.9	44.2	25.3
Managing three visible buttons			11.7	3.9			114.0	16.3	100.6	20.0	40.3	17.0	47.5	9.0
Zipping a garment			2.2	0.9			94.9	14.6	71.3	11.7	41.6	17.8	48.4	6.2
Putting on gloves	5.4	2.5			6.4	3.0	93.0	34.7	90.3	27.5	57.2	26.5	63.5	21.3
Dialing a telephone			8.7	1.4			92.5	7.3	85.8	13.4	59.0	15.8	64.8	9.5
Tying a bow			6.4	2.4			112.4	20.4	108.6	25.3	47.6	18.9	55.5	18.0
Manipulating safety pins			5.0	1.9			115.0	22.3	105.0	12.1	42.5	17.5	70.0	15.0
Picking up coins			5.2	1.2			92.5	13.0	87.9	20.8	34.9	16.3	61.3	14.1
Threading a needle			3.3	2.5			122.0	40.2	104.8	24.9	39.1	20.2	72.5	11.6
Unwrapping a Band-Aid	8.8	3.0			10.3	4.1	83.4	25.9	74.3	18.0	30.5	18.5	39.6	9.4
Squeezing toothpaste			2.8	1.4			107.0	25.4	73.2	15.6	36.4	11.3	51.2	12.4
Cutting with a knife	5.9	2.4			7.4	2.4	110.4	21.9	84.3	17.6	45.6	20.2	53.0	19.6
Using a fork			1.4	0.5			100.0	23.6	86.9	15.9	42.2	12.7	52.8	11.3
NPE														
Test anxiety questionnaire			27.0	14.3			91.4	34.9	109.0	45.5	116.0	45.8	82.0	16.5
Counting			70.4	33.8			89.0	12.9	87.7	15.3	67.9	17.6	74.6	16.0
Similarities			19.7	4.8			93.0	18.2	85.8	17.8	84.0	18.4	73.1	26.0
Digits forward			7.3	2.6			96.6	15.9	88.3	7.1	84.1	13.7	91.0	14.8
Digits backward			5.6	2.5			79.3	17.4	73.9	15.8	77.5	19.1	72.1	19.0

[1]Scores for the D (Dominant) and N (Nondominant) body sides of young adult normal subjects are not combined when the difference in means is at least 10 per cent and $p \leq 0.05$. All subjects declared themselves right-handed. For test units, refer to Table 1 in [3]. Abbreviated terms include: QENF, Quantitative Examination of Neurological Function; CQNE, Clinical Quantitative Neurological Examination; SADLE, Simulated Activities of Daily Living Examination; NPE, Neuro-Psychological Examination; MS, multiple sclerosis; PD, Parkinson's Disease.

[2]The scores for young adult males and for young adult females are not combined when the difference in means is at least 10 per cent and $p \leq 0.05$.

Since the experimental design and purpose for the study involves the discovery of differences between the three groups of normal subjects who span different age ranges, the results are described in terms of the analysis of variance and the Duncan New Multiple Range Test [10]. The following general observations can be made:

Although the eldest subjects tend to have poorest vision, there are no significant differences in vision among the subject groups.

There are no significant differences among the groups in the strength tests. The middle aged normal subjects are stronger than the young adult normal subjects, but not significantly so.

In the sub-battery of steadiness tests, all tests performed in a supported position indicate that steadiness supported decreases with increasing age. However, all the tests performed in an unsupported position indicate that age has no effect on steadiness unsupported.

The speed tests for the hand and foot show no significant effects of age on performance. In the Foot Speed-*N** test, the middle aged normal subjects did not perform as well as the older aged normal subjects, perhaps a technical difference.

Tests reflecting coordination of either the upper or lower extremities show mixed results. Significant effects of age were found on tests of hand coordination 1 (for the dominant but not for the nondominant body side), hand coordination 2, rotary pursuit (at 30 rpm but not at 60 rpm), purdue pegboard, pencil rotation (for the dominant but not for the nondominant body side), tandem gait with and without supports, and for 8 of 13 tests in the Simulated Activities of Daily Living Examination (SADLE).

Performance on tests that attempt to measure fatigue is invariant with age.

Without question, the number of errors committed in coordination tests decreases with age. Significant effects are found for measures of hand coordination errors and for foot coordination errors.

Tests of vibration sense and two-point discrimination show highly significant decreases in performance with increasing age.

In the Neuro-Psychological Examination, the Similarities and Digits Backward tests show significant decreases with increasing age, while the Counting and Digits Forward tests show a nonsignificant trend in the same direction. Performance in the Test Anxiety Questionnaire is invariant with age.

Per cent normal function

The analysis of age effects indicates that performance on many tests in the QENF decreases with increasing age. As indicated earlier, the normalization technique that converts the performance of patients to a percentage of normal function should be used with caution since the normal function of subjects of various age groups differs. The present results can be reassessed by expressing the performance of the two older subject groups and the multiple sclerosis and parkinsonian patient groups as a percentage of the normal function of the young adult normal subjects (see Table 2).

For each QENF test each subject's performance was expressed as a percentage of normal function. From this, the means and standard deviations for each group of

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* denotes nondominant body side and N denotes dominant body side.

TABLE 3. PERFORMANCE OF MS PATIENTS IN THE QENF[1] EXPRESSED AS A PERCENTAGE OF MATCHED NORMAL FUNCTION

	Matched normal function for MS patients						% of matched normal function	
	5 males		5 males + 5 females		5 females		10 MS patients	
Test	Mean	±2SD	Mean	±2SD	Mean	±2SD	%	SD
CQNE, vision								
Corrected near vision			100.0	0.0			71.8	29.7
Corrected distance vision			98.7	4.7			74.3	19.0
Near and distance vision			99.3	2.3			73.1	20.6
Pinhole vision			91.2	27.6			85.0	18.3
CQNE, upper extremities								
Grip strength, 2	99.4	25.3			61.2	11.8	90.2	45.8
Wrist dorsiflexion strength–D	63.4	14.2			35.0	8.1	68.2	38.3
Wrist dorsiflexion strength–N	53.7	25.0			34.9	9.7	76.0	31.2
Shoulder abduction strength	35.2	13.7			18.3	5.4	71.8	39.6
Hole steadiness, supported			2.1	0.3			68.0	19.3
Hole steadiness, unsupported			6.2	2.3			48.2	17.3
Force steadiness, supported			3.4	2.9			78.3	39.6
Force steadiness, unsupported			9.2	9.2			100.0	47.8
Resting tremor			0.7	0.6			125.2	64.7
Sustention tremor	2.5	1.0			1.8	0.7	73.1	26.6
Static intention tremor			1.5	1.5			85.3	45.1
Simple reaction time			8.4	2.2			66.2	14.2
Hand speed, 1–D			65.1	14.0			49.5	17.3
Hand speed, 1–N			57.9	10.7			49.9	19.9
Hand speed, 2			67.0	11.8			62.3	12.2
Hand coordination, 1–D			36.8	9.6			39.7	14.6
Hand coordination, 1–N			29.9	8.1			52.5	19.8
Hand coordination errors, 1	1.2	0.9			0.4	2.3	140.0	86.9
Hand coordination, 2			10.0	2.3			51.7	13.8
Hand coordination errors, 2			3.7	3.7			162.0	102.7
Rotary pursuit, 30 rpm–D			51.3	22.8			14.7	11.4
Rotary pursuit, 30 rpm–N			42.2	23.8			22.3	14.8
Rotary pursuit, 60 rpm–D			8.7	10.5			9.9	8.4
Rotary pursuit, 60 rpm–N			5.5	10.7			21.0	28.6
Purdue pegboard			14.9	2.8			33.8	18.7
Large peg rotation			11.7	4.5			51.5	26.1
Small peg rotation			11.3	4.8			46.3	19.5
Pencil rotation–D			13.9	1.9			46.6	10.0
Pencil rotation–N			12.1	1.9			46.3	14.0
Grip strength fatigue			82.1	18.2			111.0	20.5
Hand speed fatigue			81.9	12.2			98.1	16.9
Touch sense of hand			6.0	0.0			100.0	0.0
Vibration sense of finger, 1	1.2	0.5			2.2	1.7	60.8	52.7
Vibration sense of finger, 2			1.1	3.6			140.0	129.0
Position sense			1.0	0.0			97.5	7.9
Two-point discrimination			3.8	1.0			66.7	26.3
CQNE, lower extremities								
Foot dorsiflexion strength	83.3	26.7			53.3	30.2	33.1	41.0
Hip flexion strength	39.0	20.4			20.1	10.2	19.6	28.5
Foot speed–D			51.5	16.1			21.2	20.9
Foot speed–N			43.0	13.8			36.5	27.4
Foot coordination			6.3	0.8			22.9	21.4
Foot coordination errors			2.2	4.6			207.0	203.0
Two leg standing, eyes open			30.0	0.0			55.0	48.5

TABLE 3. *Continued*

Test	Matched normal function for MS patients[2] 5 males Mean	±2SD	5 males + 5 females Mean	±2SD	5 females Mean	±2SD	% of matched normal function 10 MS patients %	SD
One leg standing, eyes open			30.0	0.0			4.5	9.6
Two leg standing, eyes closed			30.0	0.0			21.7	41.6
One leg standing, eyes closed			27.6	11.3			0.0	0.0
Tandem gait with supports			2.9	1.1			22.4	20.7
Tandem gait without supports			2.8	1.1			8.5	18.0
Foot speed fatigue			79.3	32.6			121.2	56.4
Touch sense of toe			5.7	1.0			82.5	32.3
Vibration sense of toe, 1			5.7	10.5			18.0	35.2
Vibration sense of toe, 2			9.3	25.5			29.5	30.7
Position sense			1.0	0.0			72.5	24.9
SADLE								
Putting on a shirt			8.1	7.0			45.1	28.2
Managing three visible buttons	11.4	3.0			9.6	2.1	36.3	15.4
Zipping a garment			2.3	0.8			44.9	19.1
Putting on gloves			7.4	6.6			72.1	32.6
Dialing a telephone			9.4	1.4			64.1	17.2
Tying a bow			5.8	1.9			43.5	17.3
Manipulating safety pins	5.3	0.8			3.8	0.7	38.6	17.5
Picking up coins			5.7	1.7			38.4	17.9
Threading a needle			3.1	3.3			37.4	19.3
Unwrapping a Band-Aid			12.1	5.3			39.0	23.0
Squeezing toothpaste			2.8	1.2			35.5	11.0
Cutting with a knife			6.2	1.7			41.7	15.8
Using a fork			1.5	0.7			44.2	13.4
NPE								
Test anxiety questionnaire			32.6	18.1			140.0	55.3
Counting			68.0	27.1			70.3	18.2
Similarities			18.3	7.2			90.2	19.8
Digits forward			7.0	2.3			87.1	14.2
Digits backward	3.8	0.9			5.0	2.0	98.6	22.9

[1]Scores for the D (Dominant) and N (Nondominant) body sides of matched normals for the MS patients are not combined when the difference in means is at least 10 per cent and $p \leq 0.05$. All subjects declared themselves right-handed. For test units, refer to Table 1 in [3]. Abbreviated terms include: QENF, Quantitative Examination of Neurological Function; CQNE, Clinical Quantitative Neurological Examination; SADLE, Simulated Activities of Daily Living Examination; NPE, Neuro-Pyschological Examination; MS, multiple sclerosis.

subjects were obtained. Results are shown in Table 2. Because performance by young adult male subjects can be significantly different on some tests from performance by young adult normal female subjects [3], the percentage of normal function for each of the four groups shown in Table 2 was obtained separately for each sex on those tests and then combined.

From Table 2, the following observations are made:

The performance of the 10 normals matched to the multiple sclerosis patients does not differ appreciably from that of young adult normal subjects.

TABLE 4. PERFORMANCE OF PD PATIENTS IN THE QENF[1] EXPRESSED AS A PERCENTAGE OF MATCHED NORMAL FUNCTION

	Matched normal function for PD patients						% of matched normal function	
	5 males		5 males + 5 females		5 females		10 PD patients	
Test	Mean	±2SD	Mean	±2SD	Mean	±2SD	%	SD
CQNE, vision								
Corrected near vision			97.8	13.9			83.7	26.2
Corrected distance vision			94.4	17.6			94.5	13.6
Near and distance vision			96.1	11.1			89.0	18.7
Pinhole vision			91.7	15.6			95.4	11.3
CQNE, upper extremities								
Grip strength, 2	86.1	47.3			43.9	27.3	82.2	33.0
Wrist dorsiflexion strength	50.0	17.2			24.9	13.4	89.9	38.0
Shoulder abduction strength	26.0	7.5			13.1	7.3	90.5	48.4
Hole steadiness, supported			2.8	1.5			64.0	31.6
Hole steadiness, unsupported			8.1	6.6			60.0	26.6
Force steadiness, supported	6.6	2.6			4.1	3.4	89.5	59.8
Force steadiness, unsupported–D			10.5	5.4			104.0	77.1
Force steadiness, unsupported–N	11.4	6.8			7.3	3.8	86.3	49.0
Resting tremor			1.0	0.9			117.0	120.0
Sustention tremor			3.2	4.3			73.8	50.2
Static intention tremor			2.1	1.9			67.0	46.3
Simple reaction time			9.8	2.5			89.9	20.6
Hand speed, 1			59.0	18.9			59.9	17.7
Hand speed, 2			63.3	16.8			83.0	15.0
Hand coordination, 1			31.1	8.3			70.3	13.0
Hand coordination errors, 1–D	1.8	0.9			0.2	0.9	194.0	175.0
Hand coordination errors, 1–N			0.2	1.3			34.3	12.7
Hand coordination, 2			9.3	2.0			69.1	12.0
Hand coordination errors, 2			2.6	2.7			165.3	86.9
Rotary pursuit, 30 rpm–D			46.8	27.9			35.2	20.7
Rotary pursuit, 30 rpm–N			37.5	29.8			69.2	36.6
Rotary pursuit, 60 rpm	14.5	17.4			3.4	4.8	31.9	29.1
Purdue pegboard			13.6	3.4			67.5	11.6
Large peg rotation			13.0	5.9			73.8	10.2
Small peg rotation			12.4	2.7			71.0	10.4
Pencil rotation–D			12.8	6.3			56.0	17.3
Pencil rotation–N			11.3	5.0			53.5	18.1
Grip strength fatigue			83.1	14.8			108.0	15.4
Hand speed fatigue			86.5	18.7			103.0	11.2
Touch sense of hand			6.0	0.0			100.0	0.0
Vibration sense of finger, 1			2.9	4.2			132.0	61.5
Vibration sense of finger, 2			1.5	2.3			355.0	361.0
Position sense			1.0	0.0			100.0	0.0
Two-point discrimination			4.2	1.3			90.3	14.3
CQNE, lower extremities								
Foot dorsiflexion strength	71.4	23.4			42.9	11.2	93.4	32.5
Hip flexion strength	27.8	10.3			16.1	8.8	74.9	41.7
Foot speed	54.5	11.6			43.1	8.4	75.7	23.7
Foot coordination			6.0	1.3			66.2	21.4
Foot coordination errors			2.7	2.5			204.9	87.8
Two leg standing, eyes open			30.0	0.0			100.0	0.0

TABLE 4. *Continued*

One leg standing, eyes open			25.2	18.5			29.2	41.2
Two leg standing, eyes closed			30.0	0.0			100.0	0.0
One leg standing, eyes closed	16.4	18.6			5.7	6.5	21.6	35.7
Tandem gait with supports			2.3	1.1			68.4	14.3
Tandem gait without supports			2.2	1.1			63.8	19.1
Foot speed fatigue			80.4	18.9			96.7	15.7
Touch sense of toe			5.4	2.4			88.8	23.0
Vibration sense of toe, 1			26.4	57.3			94.9	138.0
Vibration sense of toe, 2			18.0	34.7			229.0	292.0
Position sense			1.0	0.0			97.5	5.3
SADLE								
Putting on a shirt			7.9	2.8			46.9	26.8
Managing three visible buttons			12.0	4.0			48.6	9.3
Zipping a garment			3.1	1.1			69.7	8.9
Putting on gloves	5.1	2.3			9.2	3.7	79.0	38.1
Dialing a telephone	9.3	2.6			11.3	2.4	77.8	17.7
Tying a bow			6.1	2.5			53.4	17.3
Manipulating safety pins			4.8	1.1			67.5	14.5
Picking up coins			6.3	4.3			75.0	17.3
Threading a needle			3.3	2.0			73.8	11.8
Unwrapping a Band-Aid			14.1	12.7			58.7	12.9
Squeezing toothpaste			4.0	1.7			72.8	17.6
Cutting with a knife			8.2	4.2			65.4	22.7
Using a fork	1.5	0.3			1.9	0.6	63.0	16.9
NPE								
Test anxiety questionnaire			28.7	22.7			87.2	17.5
Counting	70.2	15.3			53.2	9.6	87.4	25.8
Similarities			16.9	7.0			85.2	30.3
Digits forward			6.4	1.0			103.1	16.8
Digits backward			4.1	1.8			97.6	25.7

[1]Scores for the D (Dominant) and N (Nondominant) body sides of matched normals for the PD patients are not combined when the difference in means is at least 10 per cent and $p \leq 0.05$. All subjects declared themselves right-handed. For test units, refer to Table 1 in [3]. Abbreviated terms include: QENF, Quantitative Examination of Neurological Function; CQNE, Clinical Quantitative Neurological Examination; SADLE, Simulated Activities of Daily Living Examination; NPE, Neuro-Psychological Examination; PD, Parkinson's Disease.

The performance of the 10 normals matched to the parkinsonian patients is less than that for the two younger normal subject groups on many tests.

The performance of the two patient groups is considerably less than that of any normal subject group.

Tests that have been shown to have significant effects of age on performance (Table 1) are reasonably evident from examination of Table 2.

Tests that have shown a high variability in performance for patients [3] also indicate a lower percentage of normal function.

The older normal subject groups and the patient groups make fewer errors than young adult normal subjects on tests that involve both speed and accuracy.

Tables 3 and 4 show the performance of the multiple sclerosis and parkinsonian patients as a percentage of normal function based upon the normal groups which

were specifically matched to the patient groups. The differences in percentage of matched normal function for multiple sclerosis patients between Tables 2 and 3 are small. Far greater differences, however, are easily observable for Parkinson's disease patients between Tables 2 and 4.

Composite scores

The above results can be seen more easily from composite scores of a selected number of CQNE and SADLE tests (see Table 5). The performance of multiple sclerosis patients on both the CQNE and SADLE composites expressed as a percentage of normal function of young adult normal subjects or matched normal subjects differs by less than 2 per cent. However, the same analysis for the parkinsonian patients indicates a difference exceeding 10 per cent.

Tables 2, 3 and 4 contain much data, making visual analysis difficult. Composite scores can be used to combine data or related tests to meaningfully reduce data for easier analysis. Figure 1 illustrates the method. The data from tests measuring the same primary category of neurological function have been combined and averaged for multiple sclerosis and parkinsonian patients from Tables 3 and 4, respectively. The categories affected by the disease can readily be determined for both the multiple sclerosis and parkinsonian patients. Compared to other data reduction methods reviewed by Potvin [3], this method appears to provide more meaningful indices of neurological function.

DISCUSSION

The results of age on performance indicates that the middle aged subjects are stronger than the young subjects. Although the trend may result from differences other

TABLE 5. COMPARISON[1] OF CQNE AND SADLE PERFORMANCE FOR PD AND MS PATIENTS WHEN THEIR PERFORMANCE IS EXPRESSED AS A PERCENTAGE OF NORMAL FUNCTION

Patients	Normal subject group	Mean % CQNE[2]	Mean % SADLE[3]	% Diff.[4]	Paired $\lvert t \rvert$ value
10 PD	40 young adult normals	59.2	55.7	4.8†	1.82
10 PD	10 matched normals	72.2	65.5	7.8†	2.19*
10 MS	40 young adult normals	46.2	43.0	7.8†	1.73
10 MS	10 matched normals	44.6	44.7	0.7	0.08

[1]All subjects declared themselves right-handed. Abbreviated terms include: CQNE, Clinical Quantitative Neurological Examination; SADLE, Simulated Activities of Daily Living Examination; PD, Parkinson's Disease; MS, multiple sclerosis.

[2]CQNE tests include: Force steadiness, supported-D, N; Force steadiness, unsupported; Simple reaction time; Hand speed, 2-D, N; Hand coordination, 1-D, N; Hand coordination, 2; Rotary pursuit, 60 rpm-D, N; Purdue pegboard; Small peg rotation; Pencil rotation-D, N; Foot speed; Foot coordination; Tandem gait with supports.

[3]SADLE tests include: Putting on a shirt; Managing three visible buttons; Zipping a garment; Putting on gloves; Dialing a telephone; Tying a bow; Manipulating safety pins; Picking up coins; Threading a needle; Unwrapping a Band-Aid; Squeezing toothpaste; Cutting with a knife; Using a fork.

[4]Per cent difference $= 100/n \left| \Sigma[(\%\,\text{SADLE} - \%\,\text{CQNE})/(\%\,\text{CQNE})] \right|$, where $n = 10$, the number of patients.

*$p \leq 0.05$.

†Indicates better performance on CQNE than on SADLE.

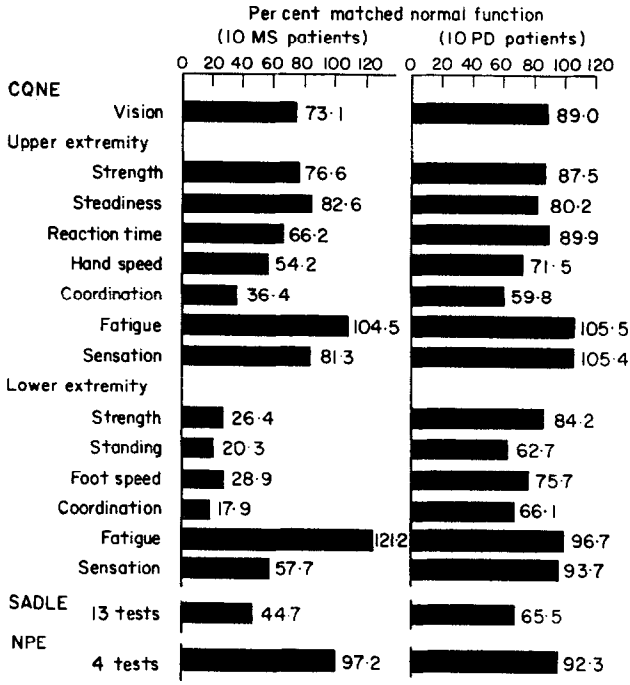

FIG. 1. Comparison of the performance of MS and PD patients when performance is expressed in functional categories as a percentage of matched normal function (refer to text and Table 5).

than age (such as socioeconomic differences), others have also reported a similar trend [11–13].

The differences in results found in the sub-battery of steadiness tests between tests performed in the supported and in the unsupported position are not in agreement with Albers in an earlier study [14, 15]. His sample included a group of 20 right-handed young adult normal subjects (mean age=22.4 yr, standard deviation=2.7 yr) and a group of 7 right-handed older adult normal subjects (mean age=56.7 yr, standard deviation =3.2 yr). With a larger sample group, Albers might have found significant differences.

From the results shown in Table 1, it appears that only tests requiring fine skilled movements primarily with the dominant hand show significant deterioration of performance with increasing age. Examination of the tests in the SADLE reveals that performance on tests requiring two hands, such as Putting on a Shirt, Managing Three Visible Buttons, Putting on Gloves, Tying a Bow, Manipulating Safety Pins and Threading a Needle, is invariant with age. On the remaining SADLE tests requiring skilled movements primarily with the dominant hand, performance deteriorates significantly with increasing age.

The decrease in the number of errors committed in the coordination tasks as age increases is in agreement with Welford's results [16]. He found that older subjects, when given the opportunity to shift between speed and accuracy, tend toward increased accuracy. He implied a biological reason for this shift – as people age they become increasingly careful in their habits to avoid injury.

Comparisons of age results in the Neuro-Psychological Examination are confounded by the higher educational level achieved by the young adult normal subjects. The results obtained may nonetheless reflect differences that can be attributed to age.

Where age differences in performance are significant, the Duncan New Multiple Range Test indicates that the performance of the group of oldest subjects is significantly worse than for both younger groups. The two younger groups are found to be significantly different in their performance for only two tests, Digits Backward and Vibration Sense of Finger 2. As mentioned above, the younger group's superior performance in the Digits Backward test may be attributed to differences other than age among the populations sampled. The difference in the vibration sense test may be technical; the difference is not found for the more reliable [3] Vibration Sense of Finger 1 test. This general finding for the two younger groups indicates that performance in tests that span a broad range of human function does not change appreciably, at least up to the mid-forties, in agreement with the results of many other researchers (e.g. [9, 16]).

Differences in performance between the young adult normal group and the two older adult normal groups can conceivably be attributed to differences in motivation. The two older adult normal groups were family members of patients and might be motivated to perform at a higher level than the paid non-emotionally involved young adult control group. However, a second study performed with these same subject groups showed that this hypothesis is false: all subject groups are uniformly motivated [17].

When the performance of patients is expressed as a percentage of matched normal function, only slight differences are seen for the middle-aged multiple sclerosis patients when compared to the same performance expressed as a percentage of young adult normal function. For the elderly parkinsonian patients, however, the net result of using young adult normal controls (instead of matched controls) is to decrease the apparent function of the patients. In a therapeutic trial, this procedure could conceivably lead to erroneous conclusions, as discussed earlier.

SUMMARY

Forty young adult normal subjects, 10 Parkinson's disease patients and their 10 matched normal subjects, and 10 multiple sclerosis patients and their 10 matched normal subjects were evaluated in the Quantitative Examination of Neurological Function to determine age effects and the importance of selecting closely matched normal control groups for assessing the performance of patients. Where there are significant differences among the three normal subject groups, it is the oldest normal subject group that differs from the two younger subject groups. Significant decreases in performance with increasing age were found for the steadiness tests performed in the supported position, the sensation tests, two or five tests in the Neuro-Psychological Examination and tests requiring fine skilled movements primarily with the dominant hand. It was found that older subjects made fewer errors in coordinated tasks.

A normalization technique, expressing performance as a percentage of normal function, was introduced. A method was developed to provide quantitative and meaningful indices of neurological function. The measure is obtained by averaging the percentage of normal function scores over several tests that belong to a primary category of neurological function.

Young adult normal subjects do not perform significantly better than normal subjects in the age range of multiple sclerosis patients; however, young adult normal subjects do perform significantly better than normal subjects in the age range of Parkinson's disease patients, especially on tasks requiring fine skilled movements of the dominant hand and coordinated activities of the lower extremities. These results indicate that the performance of multiple sclerosis patients can be expressed as a percentage of the function of either age-matched normal controls or young adult normal controls. However, the performance of Parkinson's disease patients should be expressed only as a percentage of the function of age-matched normal controls.

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