

From the Hospital for Physical Medicine, Hald near Viborg, Denmark
(Head: Niels Bukh) and the Orthopaedic Hospital, Aarhus, Denmark
(Head: Professor Eivind Thomasen, M.D.).

MUSCLE RECOVERY IN POLIOMYELITIS

By

NIELS BUKH

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Investigations of the recovery of completely or partly paralysed muscles by regular manual testing of muscle power during the first years after the onset of poliomyelitis have previously been performed by *Lovett* (1915), *Skinhøj* (1949), *Seddon* (1955), *Sharrard* (1955), and others.

The present paper reports a follow-up through 5½ years of patients treated, after the 1952 and 1953 epidemics, primarily in the Hospital for Physical Medicine, Hald near Viborg, and in the Orthopaedic Hospital, Aarhus, i.e. patients from Jutland and Funen.

According to the figures published by the National Health Service these two epidemics counted a total of 3134 paralytic cases, 2560 in the 1952 epidemic and 574 in the 1953 epidemic. Out of these 3134 paralysed patients 1215 were domiciled in Jutland or Funen. In this area there were 183 fatal cases. Of the remaining 1032 paralytic cases 508 had their primary after-treatment in the named hospitals. Out of these 508 patients 258 were males and 250 females. 155 were over 15 years of age. Of the 353 children 173 were under 4 years. The age distribution is the same as that for the paralysed patients in the whole of Denmark, viz. about 30 per cent adults and 70 per cent children under 15 years of age.

To obtain an assessment of muscle recovery as reliable as possible, 240 patients were selected from the 508. These were partly patients whose first muscle test was carried out within 3 months of the onset of poliomyelitis, and partly children over 4 years of age. The group comprised, then, 117 adults and 123 children in the age range 4-15 years.

Muscle recovery was recorded in these 240 cases by regular tests through 5½ years. The calculations were based upon 6 tests done:

- (1) an average of 6 weeks after the onset of poliomyelitis
 (2) " " " 3 months " " " " "
 (3) " " " 6 months " " " " "
 (4) " " " 1 year " " " " "
 (5) " " " 2 years " " " " "
 (6) " " " 5½ years " " " " "

The evaluation was done by manual testing of the power of each individual muscle in a systematic test of the most important muscles. All the tests were performed by the same two examiners (N. B. and E. T.). In assessing muscle power the grading suggested by *Lovett* was used:

- 0 = No contraction.
 1 = Trace of contraction.
 2 = Active movement with gravity eliminated.
 3 = Active movement against gravity.
 4 = Active movement against gravity and some resistance.
 5 = Normal power.

Muscles having grade 3 power or over were listed as muscles of functional value.

At the first test, done an average of 6 weeks after the onset of polio, the following results were recorded:

919 grade 0 muscles			
1483	"	1	"
1643	"	2	"
2029	"	3	"
2006	"	4	"
Total	8080 muscles		

If the improvement in muscle power during the 5½ years of the follow-up is taken to be 100, about 50 per cent of the improvement occurred within the first 6 months after the onset of polio, about 75 per cent within the first year, and 90–95 per cent within the first 2 years. The findings for grade 0 muscles were somewhat different, the improvement in these muscles within the first 6 months being 70 per cent and within the first year almost 90 per cent (Figure 1).

Skinhøj found that of 702 grade 0 muscles in his study 70 per cent were still grade 0 at follow-up 3 years later and that only 12 per cent were of functional value.

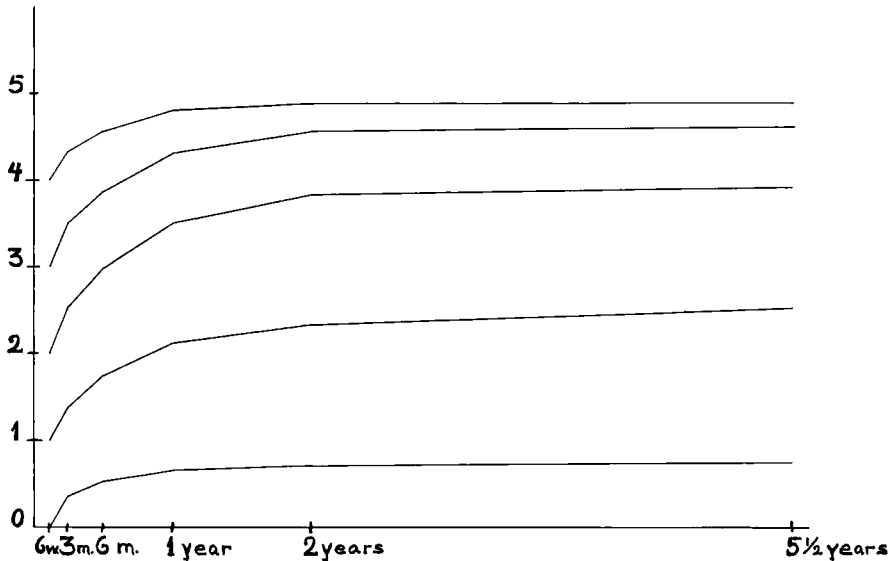


Figure 1. Muscle recovery through 5½ years for all muscles of grade 0, 1, 2, 3, and 4 from all 240 patients.

In the present material 80 per cent of 919 grade 0 muscles remained grade 0 or 1 at the end of 5½ years, while 10 per cent had attained functional value.

Out of the 682 muscles which were still grade 0 three months after the onset of polio, 95 per cent remained grade 0 or 1 at the end of 5½ years, and only 2.5 per cent were of functional value.

Correspondingly, of the 600 grade 0 muscles at 6 months 97 per cent still remained grade 0 or 1 at the end of 5½ years, and only ½ per cent had attained functional value.

In other words, a muscle which remains grade 0 three months after the onset of polio has a very poor prognosis.

The prospects for grade 1 and 2 muscles in the present material were as follows:

Of 1483 grade 1 muscles 50 per cent had gained functional value at the end of 5½ years.

Of 1643 grade 2 muscles 88 per cent had gained functional value at the end of 5½ years.

Skinhøj reported that of 575 grade 1 and 2 muscles 56 per cent were of functional value at the end of 3 years.

A comparison of muscle recovery in children and adults showed

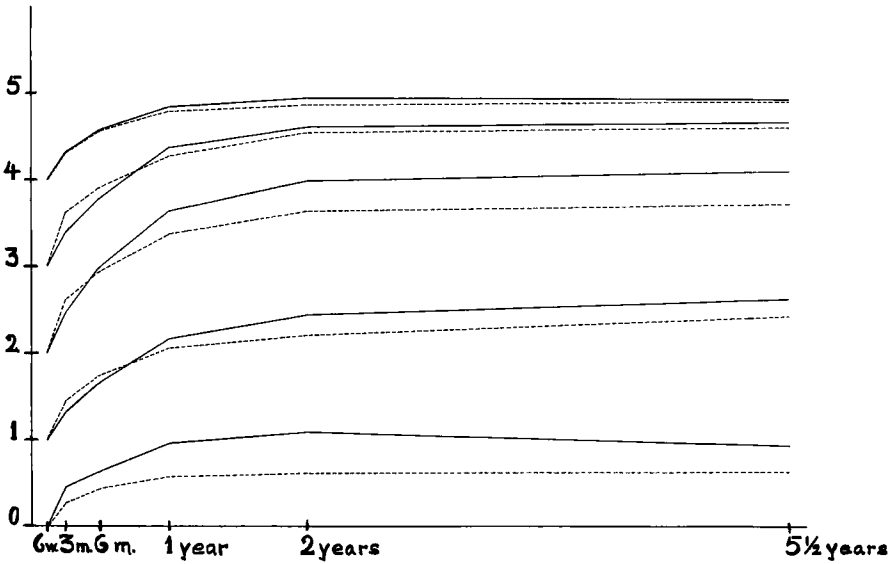


Figure 2. Muscle recovery through 5½ years for all muscles of grade 0, 1, 2, 3, and 4: In patients over 15 years of age: solid line. In patients aged 4-15 years: dotted line.

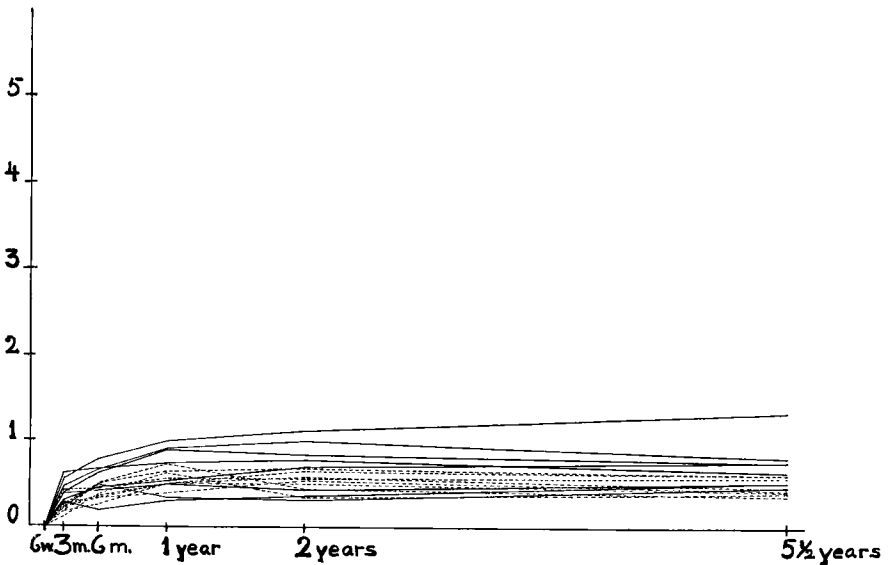


Figure 3. Muscle recovery through 5½ years for all grade 0 muscles in the lower limbs. Muscles above the knee: solid line. Muscles below the knee: dotted line.

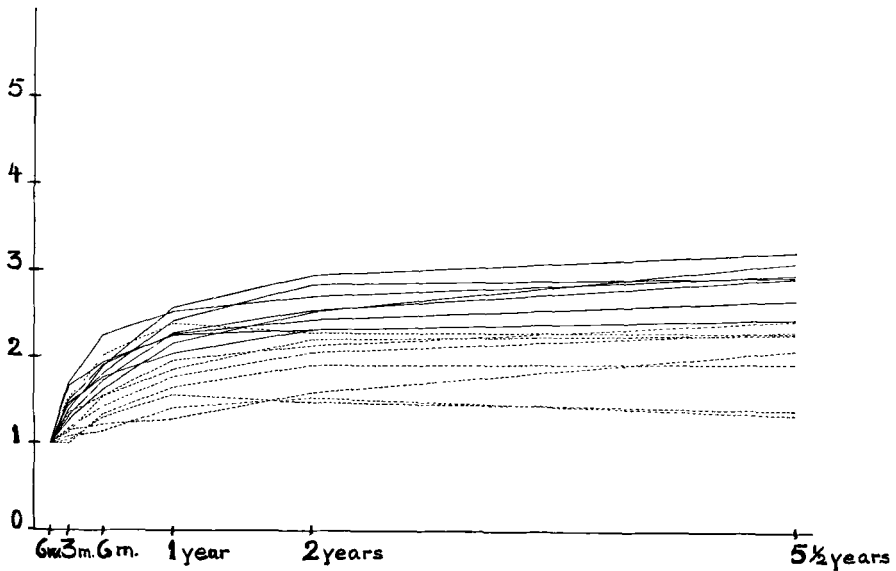


Figure 4. Muscle recovery through 5½ years for all grade 1 muscles in the lower limbs. Muscles above the knee: solid line. Muscles below the knee: dotted line.

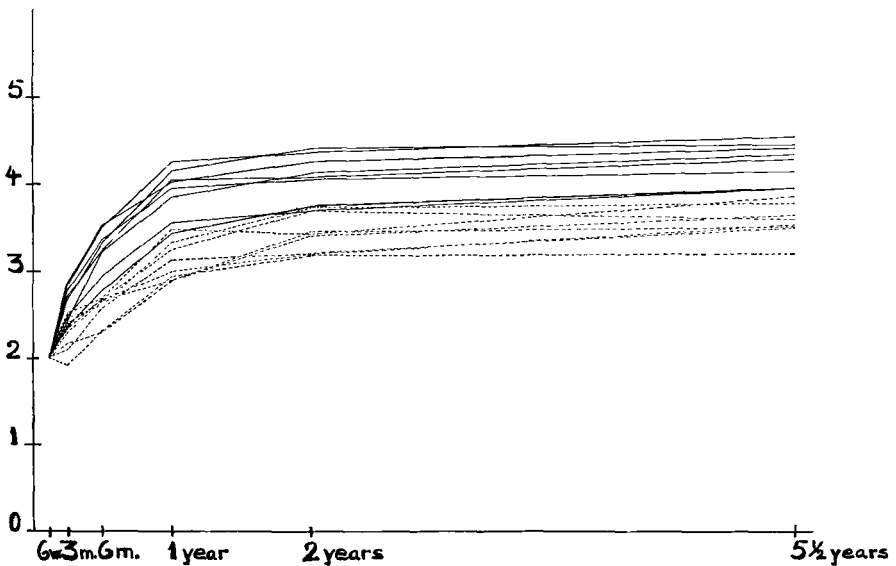


Figure 5. Muscle recovery through 5½ years for all grade 2 muscles in the lower limbs. Muscles above the knee: solid line. Muscles below the knee: dotted line.

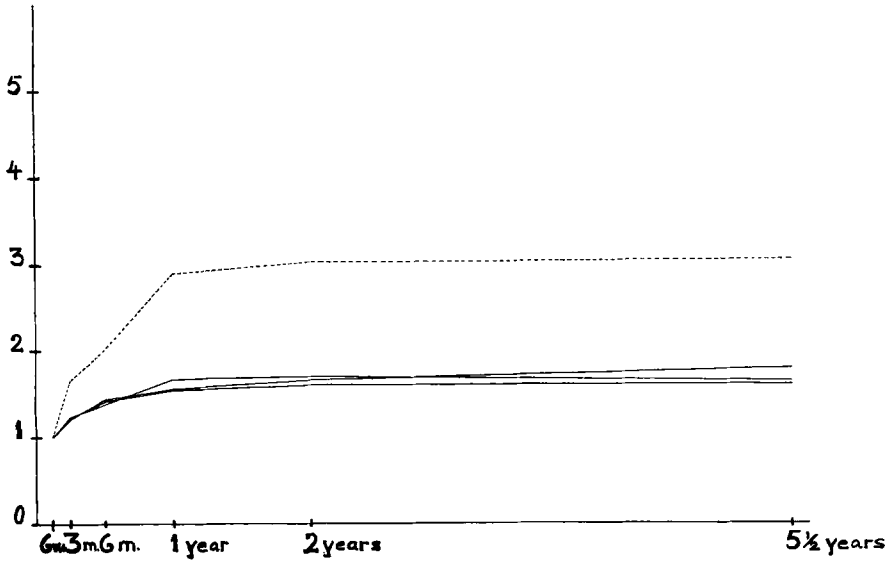


Figure 6. Muscle recovery through 5½ years for all grade 1 abdominal muscles: solid line, and all grade 1 back muscles: dotted line.

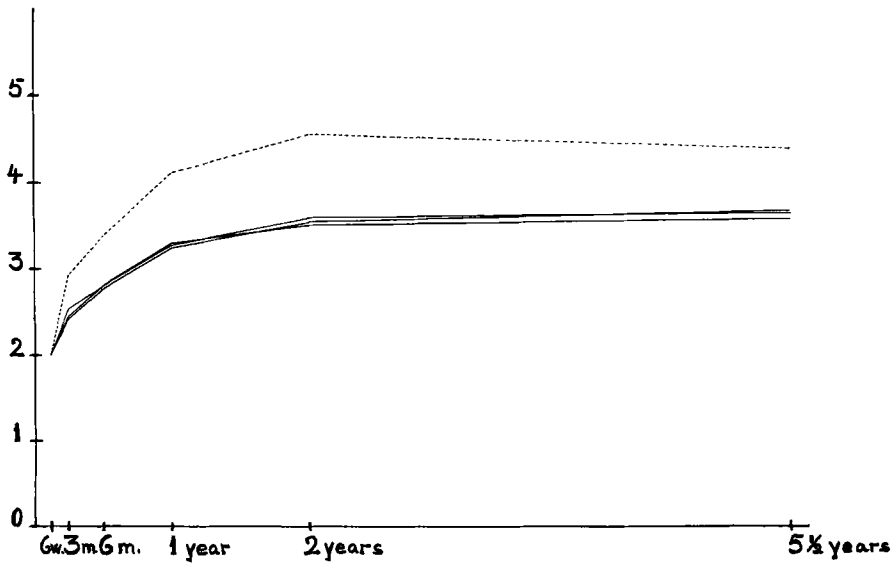


Figure 7. Muscle recovery through 5½ years for all grade 2 abdominal muscles: solid line, and all grade 2 back muscles: dotted line.

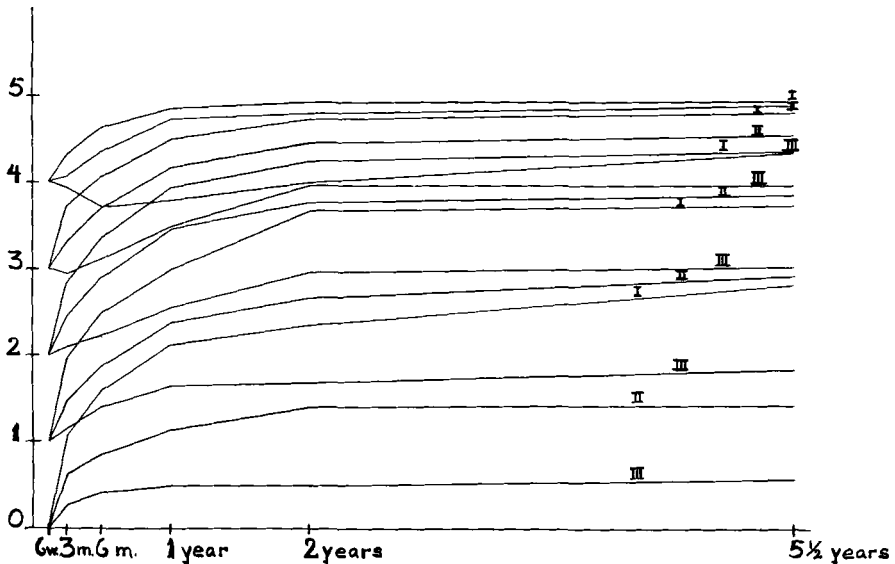


Figure 8. Muscle recovery through 5½ years for all grade 0, 1, 2, 3, and 4 muscles from all 240 patients, divided into three sub-groups according to their site, i.e. in limbs having degree I, II, or III total paralysis.

hardly any definite difference in the present material (Figure 2). A finding of better regeneration in children by previous workers may be due to the inclusion of children under 4 years of age in whom the assessment of muscle function must be fairly uncertain.

In respect to the ability of the individual muscles to recover, the proximal groups of muscles in the lower limbs seemed to have a somewhat better prognosis than the peripheral ones. This is in keeping with previous findings (Figures 3, 4, and 5). In the upper limbs it has not been possible to demonstrate any definite difference between proximal and peripheral muscles, apart from the poor outlook for the opponens pollicis. The prognosis for abdominal muscles was poor, for back muscles fairly good (Figures 6 and 7). *Skinhøj's* material showed the same findings for the opponens and abdominal muscles.

A factor which appears to be of decisive importance to the prognosis of the individual muscle is the degree of paralysis in adjacent muscles, i.e. the total functional defect in the limb. In the event of severe paralysis of two or more functionally important muscles, we classified the degree of paralysis in the limb as III, i.e. a severe functional loss in the limb concerned. In these cases there are invariably severe, widespread

paralyses. With a functional defect of moderate degree the limb was listed as having a degree II paralysis and with slight functional reduction it was listed as degree I.

Table 1.

Muscle power	Time of test	Difference found in the course of the curves showing muscle recovery for all grade 0, 1, 2, 3, and 4 muscles in limbs having:		
		I-II paralysis	I-III paralysis	II-III paralysis
0	3 months	significant	significant	significant
	6 months	"	"	"
	1 year	"	"	"
	2 years	"	"	"
1	3 months	significant	significant	significant
	6 months	"	"	"
	1 year	"	"	"
	2 years	"	"	"
2	3 months	significant	significant	significant
	6 months	"	"	"
	1 year	"	"	"
	2 years	"	"	"
3	3 months	significant	significant	significant
	6 months	"	"	"
	1 year	"	"	"
	2 years	"	"	"
4	3 months	significant	significant	not significant
	6 months	"	"	" "
	1 year	"	"	" "
	2 years	"	"	" "

If the muscles found, at the first test, to be of the same degree of paralysis are divided into 3 sub-groups according to their site—*i.e.* in a limb with degree I, II, or III total paralysis—they show a decisive difference in their tendency to recover. Muscles in a severely paralysed limb show very little improvement. On the other hand, muscles in a slightly paralysed limb have a very favourable prognosis (Figure 5). This factor is of such decisive importance that even long-lasting, systematic training does not essentially alter the course; this seems important in deciding how long a systematic training should reasonably be continued. The difference between the prognosis for muscles in

*Table 2. Frequency of affection of lower-limb muscles:
Muscles listed according to frequency of involvement.*

Sharrard (142 patients)		Present material (240 patients)	
Quadriceps	184	Tibialis anterior	200
Gluteus medius	178	Gluteus medius	184
Internal popliteal	168	Iliopsoas	183
Biceps femoris	164	Tibialis posterior	176
Adductors	162	Biceps femoris	174
Iliopsoas	159	Tensor fasciae latae	171
Tibialis anterior	152	Adductors	164
Tensor fasciae latae	149	Quadriceps	162
Gluteus maximus	142	Internal popliteal	153
Tibialis posterior	140	Extensor digitorum longus	142
Flexor hallucis longus	133	Gluteus maximus	132
Flexor digitorum longus	130	Extensor hallucis longus	128
Extensor digitorum longus	130	Triceps surae	120
Triceps surae	129	Peronei	109
Peronei	126	Flexor hallucis longus	106
Extensor hallucis longus	125	Flexor digitorum longus	100

Table 3. Incidence of complete and partial paralysis of lower-limb muscles (after Sharrard 1955). Muscles listed according to frequency of complete paralysis. Ratio partial to complete paralysis. Approximate length of motor cell column in the cord.

	Number completely paralysed	Number partially paralysed	Ratio partial to complete paralysis	Approximate length of motor cell column in the cord
Tibialis anterior	103	49	0.47	8 mm
Tibialis posterior	89	51	0.57	8 mm
Flexor digitorum longus	85	45	0.52	8 mm
Flexor hallucis longus	84	49	0.58	8 mm
Extensor hallucis longus	66	59	0.89	9 mm
Extensor digitorum longus	63	67	1.06	10 mm
Peronei	60	66	1.10	10 mm
Triceps surae	57	72	1.26	14 mm
Biceps femoris	54	110	2.03	14 mm
Gluteus medius	47	131	2.78	16 mm
Quadriceps	46	138	3.00	22 mm
Internal popliteal	43	125	2.90	20 mm
Tensor fasciae latae	38	111	2.92	16 mm
Adductors	36	126	3.50	22 mm
Iliopsoas	34	125	3.67	23 mm
Gluteus maximus	33	109	3.30	17 mm

limbs with I, II, and III paralysis proved, with a single exception, to be statistically significant (Table 1¹).

Several workers, int. al. *Lovett*, *Skinhøj*, and *Sharrard*, have found that while the absolute number of affected muscles was greater for the proximal than for the distal lower limb muscles (Table 2), the number of completely paralysed muscles was greater in the lower leg and foot. On this basis *Sharrard* calculated a coefficient: partial/complete paralysis for each muscle in the lower limbs and found this coefficient to be lowest in the distal muscles. A similar analysis of our material showed a certain agreement (Tables 3 and 4). The great difference in the level of coefficients in *Sharrard's* material and ours is probably due to a difference in the severity of the epidemics and perhaps also to a difference in patient selection.

Table 4. Present material, listed in the same way as *Sharrard's* (Table 3).

	Number completely paralysed	Number partially paralysed	Ratio partial to complete paralysis	Approximate length of motor cell column in the cord
Tibialis anterior	91	109	1.20	8 mm
Tibialis posterior	52	124	2.38	8 mm
Extensor hallucis	41	87	2.12	9 mm
Peronei	40	69	1.72	10 mm
Quadriceps	38	124	3.26	22 mm
Extensor digitorum longus	37	105	2.80	10 mm
Internal popliteal	28	125	4.46	20 mm
Adductors	28	136	4.85	22 mm
Iliopsoas	27	156	5.77	23 mm
Biceps	26	148	5.69	14 mm
Flexor hallucis longus	25	81	3.24	8 mm
Flexor digitorum longus	23	77	3.35	8 mm
Triceps surae	23	97	4.22	14 mm
Gluteus medius	16	168	10.50	16 mm
Gluteus maximus	15	117	7.80	17 mm
Tensor fasciae latae	12	159	13.25	16 mm

In the same way, *Sharrard* found that the average number of completely or partly paralysed muscles supplied by a given spinal segment was largest for the L 1, L 2, and L 3 segments, falling below this level,

¹ Calculated by *Erling Dessau*.

while the average number of completely paralysed muscles supplied by a given segment was almost the same from L 4 downwards. About the same applies to our material (Table 5).

Table 5. Average number of partially or completely (2nd column) and completely (3rd column) paralysed muscles innervated from each cord segment.

Present material:

	Average number of partially or completely paralysed muscles	Average number of completely paralysed muscles
L 1	183	27
L 2	169	31
L 3	169	31
L 4	177	38
L 5	149	34
S 1	143	35
S 2	137	31

Similarly, *Sharrard*, in his very interesting pathological studies on the spinal cords from 7 polio patients, found a characteristic difference in the length of the columns of anterior-horn cells which form the nerve nuclei of the individual muscles. He demonstrated that while the proximal muscles in the hip region and in the thigh are supplied by relatively long cell columns, the cell columns for the muscles on the lower leg and foot are considerably shorter. This he took to explain the previously mentioned fact that the total number of completely or partly paralysed muscles is greater for the proximal muscles, while the number of completely paralysed muscles is larger as far as the distal muscles are concerned (Tables 3 and 4).

S U M M A R Y

Muscle recovery through 5½ years after the onset of poliomyelitis was assessed by regular testing of muscle power in 240 patients, 117 adults and 123 children over 4 years of age. The assessment was based upon manual testing of muscle power 6 weeks, 3, 6, and 12 months, 2 and 5½ years after the onset of polio. It was found that about 50 per cent of muscle recovery took place within the first 6 months, a total of about 75 per cent within the first year, and a total of 90–95 per cent within the first 2 years. As far as grade 0 muscles were concerned, however,

these findings were 70 per cent, 90 per cent, and 95 per cent respectively. A finding of great importance was that muscles which were grade 0 three months after the onset of polio had a very poor prognosis, 95 per cent remaining grade 0 or 1. As far as the grade 1 or 2 muscles were concerned, 50 per cent and 88 per cent acquired functional value in 5½ years.

In this material there did not seem to be any definite difference between muscle recovery in adults and children.

The prognosis seems somewhat better for proximal than for distal muscles in the lower limbs, poor for the opponens pollicis, and poor for the abdominal muscles.

A certain conformity was found on comparison with *Skinhøj's* and with *Sharrard's* findings. For instance, the absolute number of completely or partly paralysed muscles was found to be largest for the proximal lower-limb muscles, while the largest number of totally paralysed muscles was found in the lower leg and foot.

The ability for recovery in a muscle of any paralytic grade depends largely upon the degree of total paralysis, *i.e.* the functional defect of the limb concerned. If the total defect is severe, the prognosis is poor. If it is mild, the prognosis is favourable.

RESUME

La guérison des muscles a été étudiée pendant 5 ans et demi après une attaque de poliomyélite par le test de la force musculaire, chez 240 malades, 117 adultes et 123 enfants de plus de 4 ans. L'observation se base sur le test manuel de la force des muscles 6 semaines, 3, 6 et 12 mois, 2 et 5 ans ½ après l'attaque de polio. Il a été constaté que pour environ 50 pour cent des cas la guérison des muscles a lieu dans les premiers six mois, pour environ 75 pour cent durant la première année et pour un total de 90 à 95 pour cent durant les deux premières années. En ce qui concerne les muscles classés 0, ces données sont cependant de 70 pour cent, 90 pour cent et 95 pour cent, respectivement. Une trouvaille de grande importance est que les muscles classés 0 trois mois après l'attaque de polio ont un pronostic très défavorable, 95 pour cent restent au degré 0 ou 1. En ce qui concerne les muscles de degré 1 ou 2, 50 pour cent et 88 pour cent acquirèrent une valeur fonctionnelle dans l'espace de 5 ans et demi.

Dans ce matériel d'observation, il ne semble pas exister de différence nette entre la guérison des muscles chez les adultes et les enfants.

Le pronostic semble être un peu meilleur pour les muscles de la partie proximale des extrémités inférieures que pour ceux de la partie distale; il est mauvais pour l'opposant du pouce et pour les muscles abdominaux.

Il a été trouvé une certaine conformité en effectuant une comparaison avec les trouvailles de *Skinhøj* et de *Sharrard*. C'est ainsi que le nombre absolu des muscles entièrement ou partiellement paralysés est le plus élevé pour les muscles de la partie proximale des extrémités inférieures, alors que c'est dans la partie inférieure de la jambe et dans le pied qu'on a trouvé le plus grand nombre de muscles totalement paralysés.

La faculté de guérison d'un muscle dépend largement du degré de la paralysie générale ou de la défectuosité fonctionnelle du membre dont il s'agit. Le pronostic est défavorable si l'état général est mauvais alors que le pronostic est favorable si l'état général n'est que légèrement défectueux.

ZUSAMMENFASSUNG

Muskelerholung während $5\frac{1}{2}$ Jahren nach dem Beginn von Poliomyelitis wurde mittels regelmässiger Prüfung der Muskelkraft bei 240 Patienten, 117 Erwachsenen und 123 Kindern über 4 Jahre festgestellt. Die Schätzung hatte zur Grundlage die manuelle Prüfung der Muskelkraft 6 Wochen, 3, 6, und 12 Monate, 2 und $5\frac{1}{2}$ Jahre nach dem Beginn der Poliomyelitis. Es wurde gefunden, dass ungefähr 50 Prozent der Muskelwiederherstellung während der ersten 6 Monate stattfindet, ein Gesamtwert von ungefähr 75 Prozent innerhalb des ersten Jahres, und ein Gesamtbetrag von 90–95 Prozent innerhalb der ersten 2 Jahre. Insofern als es die Grad 0 Muskeln betraf, waren diese Befunde jedoch 70 Prozent, 90 Prozent und 95 Prozent beziehungsweise. Ein Befund von grosser Wichtigkeit war, dass Muskeln, die drei Monate nach dem Beginn der Polio Grad 0 waren, eine sehr schlechte Prognose hatten, indem 95 Prozent Grad 0 oder 1 verblieben. So weit es sich um Grad 1 und 2 Muskeln handelte, erwarben 50 Prozent und 88 Prozent einen funktionellen Wert im Verlaufe von $5\frac{1}{2}$ Jahren.

In diesem Materiale schien kein sicherer Unterschied zwischen der Muskelerholung von Erwachsenen und Kindern zu bestehen.

Die Prognose scheint etwas besser für die proximalen als für distalen Muskeln der unteren Extremität zu sein, schlecht für den Opponens pollicis und die Bauchmuskeln.

Eine gewisse Übereinstimmung mit den Befunden von Skinhøj und Sharrard wurde gefunden. Zum Beispiel—die absolute Zahl von vollständig oder teilweise gelähmten Muskeln wurde am grössten für die proximalen Muskeln der unteren Gliedmasse gefunden, während die grösste Anzahl von vollständig gelähmten Muskeln im Unterschenkel und Fuss gefunden wurde.

Die Erholungsfähigkeit eines Muskels von irgendeinem Lähmungsgrad hängt weitaus von dem Grade der totalen Lähmung ab, d.h. von dem funktionellen Defekt der betroffenen Gliedmasse. Wenn der totale Defekt schwer ist, wird die Prognose schlecht sein, ist er mild, dann ist die Prognose günstig.

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