

## PARALYTIC POLIOMYELITIS

### THE EARLY SYMPTOMS AND THE EFFECT OF PHYSICAL ACTIVITY ON THE COURSE OF THE DISEASE

BY

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Attempts to describe the early symptoms and signs of poliomyelitis present considerable difficulties, as the disease may show in many different ways. There are some excellent descriptions of the clinical features of the disease in the literature (e.g., Peabody, Draper, and Dochez, 1912), but recent epidemics have provided many more patients in the older age groups, and these can give a more detailed day-to-day account of their symptoms than has generally been available in the past. This paper is based on the careful questioning of 100 patients (59 males and 41 females) who were convalescent from poliomyelitis, and who were old enough to give a good account of their early symptoms. The number of pure bulbar cases is small, as these patients were often either unfit to be questioned or, having been discharged home after a short period of convalescence, no longer available. The method of recording the features of each case has been described (Russell, 1947), and specially prepared "Paramount" punch-cards were used for further analysis of the material.

The age groups were: under 11, 8 cases; 11-15, 21; 16-20, 17; 21-25, 20; over 25 years, 34.

The onset of the illness was in Great Britain in 85 cases, and in the remaining 15 in West Africa, the Middle East, or the Far East. Of the British cases 83 occurred during the 1947 epidemic, chiefly in the latter half of the outbreak.

#### Pattern of the Disease

In cases of paralytic poliomyelitis there may be three stages of the disease: the prodromal, the pre-paralytic, and the paralytic stages.

1. *The prodromal stage* is seen in less than half the cases, and precedes the pre-paralytic stage by several days. It consists of a brief and often slight illness lasting one or two days. Fever, sore throat, headache, or nasal catarrh are common symptoms. In most cases there is nothing specific about this stage of the disease, but in a few patients the symptoms of the prodromal stage resemble the spinal symptoms of the pre-paralytic stage.

2. *The pre-paralytic stage* is the acute and critical period of the disease. The virus is now multiplying in the central nervous system, and the battle to decide the fate of the spinal-cord cells is probably over before paralysis is detected. Spinal or meningeal symptoms develop and are often accompanied by fever, malaise, nausea, or vomiting. Pains in the spine, trunk, or limbs (spinal symptoms) are of special diagnostic value, while on examination the neck is stiff and the cerebrospinal fluid shows a marked increase of cells. Many examples of these symptoms are given below, but it must be emphasized that, though the appearance of spinal symptoms is very common, the severity of these symptoms is remarkably variable, and indeed *the pains may be so slight that the robust patient considers them*

*to be negligible.* The pre-paralytic stage usually begins abruptly, and in the 100 cases studied 89 had an abrupt onset. These can conveniently be referred to as "*typical*" cases. The cases described as "*atypical*" are those in which the onset was indefinite or in which prodromal symptoms appeared to merge into the pre-paralytic. In some cases the pre-paralytic stage appears in two phases with an interval of perhaps one or two days, during which time the patient feels he has recovered from the worst of the illness. In both these phases the spinal symptoms are often prominent.

3. *The Paralytic Stage.*—A remarkable feature of the paralytic stage is that the patient sometimes feels that he is better and that the illness is passing off, when paralysis appears. In other cases, however, severe limb pains, muscle spasm, and fever continue for many days.

*Abortive cases* are those in which no paralysis appears. There may merely be a short prodromal stage with perhaps sore throat and fever, or there may, on the other hand, be a pre-paralytic stage with spinal pains and characteristic changes in the cerebrospinal fluid. When there is only a prodromal stage the diagnosis of poliomyelitis virus infection can be little more than a guess, but when a typical pre-paralytic stage develops the diagnosis can often be made on clinical grounds with some confidence even though no paralysis occurs.

#### Prodromal Stage

As has been pointed out, the prodromal stage of the disease usually consists of a brief non-specific illness. In 34 of the 84 "*typical*" cases there were prodromal symptoms, usually lasting for one to three days and preceding the onset of spinal symptoms by an average of about five days. These symptoms often consist of a period of malaise with perhaps some fever, sore throat, headache, or cold in the head.

#### Short Prodromal Illness in a "Typical" Case

*Case 1 (2).\** Schoolgirl aged 17. *Days 1 and 2:*—Sore throat with slight anorexia. Continued to attend school. *Days 3-7:*—Felt well; school as usual. *Day 8:*—Lumbar pain; continued school. *Day 9:*—Lumbar pain less severe in the forenoon. Ballet-dancing for 1½ hours. Lumbar pain worse in the evening, spreading to abdomen. *Day 10:*—Pains worse in back, trunk, neck, and head. Some nausea. Motored 140 miles and felt very ill. *Day 11:*—Pains less severe, but some pain in thighs; fever; restless and sleepless. Trunk muscles became paralysed, and there was weakness of the thighs and left arm.

Three months later there was severe paralysis of the abdominal and trunk muscles.

\*The case notes are numbered seriatim and also according to the numbers in the records.

The occasional appearance of neurological symptoms in the prodromal stage is of special interest, as they suggest some invasion of the central nervous system by the virus even at this early stage.

*Case with Neurological Symptoms in the Prodromal Stage*

Case 2 (64). Female aged 38. Days 1-3:—Hyperaesthesia of skin of the abdomen. Day 4:—Hyperaesthesia continued; she felt well, and did an exceptionally heavy day's work in the house. Day 5:—Acute onset of pain in head and back, fever (102° F. =38.9° C.) and irritability; continued housework all day. Day 6:—Symptoms continued. Stayed in bed for half the day. Day 7:—Left leg became paralysed.

A month later there was still severe paralysis of the left thigh and trunk muscles. (See also Case 16.)

**Pre-paralytic Stage**

In considering the symptoms of the pre-paralytic stage of the disease it must first be emphasized that neither the severity of symptoms during the pre-paralytic stage nor the degree of change in the cerebrospinal fluid gives any indication of the severity of ensuing paralysis.

*Severe Pre-paralytic Symptoms but no Paralysis*

Case 3 (28).—Schoolboy aged 12. No prodromal symptoms. Day 1:—Slight headache on waking, but he went to school and played football. That evening he developed severe headache and spinal pains in the dorsal and cervical regions. He vomited and was restless and sleepless that night. Day 2:—The symptoms continued. His neck was stiff and his temperature 100° F. (37.8° C.). His body and all his limbs were painful. He was admitted to hospital. Day 3:—The cerebrospinal fluid contained 73 cells per c.mm. and 45 mg. of protein per 100 ml.

Complete recovery ensued without paralysis.

As has been pointed out, the pre-paralytic stage is the most critical period of the illness, and it is only in this stage that any serious attempt can be made to recognize the disease before the onset of paralysis. Spinal or meningeal pains are especially important in diagnosis: they were reported in 95 of the 100 cases, and are analysed in Table I. This table shows that though several spinal

tionally pain in the head may appear without any of the more common spinal pains, as in the following case. This record also provides an example in which the onset of the pre-paralytic stage was vague and indefinite.

*Indefinite Onset of Pre-paralytic Phase with Fever and Headache but No Spinal Pains*

Case 4 (39). Male student aged 19. Days 1-3:—General malaise; felt progressively more "fed-up." Day 4:—Went for a cross-country run (four miles) to try to "work off" his malaise. He did not run easily, getting home with a struggle. Day 5:—Attended lectures; no marked symptoms. Day 6:—Fever and headache. Walked with difficulty 200 yds. to tell a relative he was ill; returned to bed. Day 7:—During the night he felt ill and weak when he got up for a drink. In the morning he was helped to the lavatory, but collapsed on the floor. This was the last time he walked.

Paralysis was almost complete and permanent in both lower limbs and lower trunk.

**Spinal Pains**

The spinal pains and paraesthesiae provide by far the most characteristic clinical features of the pre-paralytic stage. They were reported in 95 of the 100 cases. They often present features which are highly specific and of considerable interest. The severity of these pains varies greatly, as the following examples show. They are often localized, and may have a segmental distribution. The severity of the pain bears no relation to the severity of ultimate paralysis, but the site of pain at the onset of the pre-paralytic stage often corresponds to the site of maximum paralysis. For example, in the present series there were 15 cases of paralytic poliomyelitis in which pains in the thighs occurred on the first day of the pre-paralytic stage. In all but one of these, a bulbar case, the paralysis was maximum in, or more often confined to, the lower limbs.

*Severe Spinal Pain Preceding Severe Paralysis*

Case 5 (50). Lieutenant in the R.N.V.R. aged 23. Day 1:—After normal duties as a barrack guard officer and a little cricket practice he developed pain in the neck at about 6 p.m. He slept badly that night. Day 2:—The pain in the neck became more severe, and in addition he developed severe sacral pain. This latter symptom made it impossible for him to rest in comfort. The buttocks were hyperaesthetic, so that he could not bear to sit or lie on his back. He went by car to report sick, but his back was so stiff that he had difficulty in getting into the car. He returned to his billet and went to bed, but could not rest; he got out of bed every hour or so to walk about for ten minutes in an unsuccessful attempt to obtain relief. He was sleepless and restless all night, moving continually while in bed in an attempt to get ease. Day 3:—Restlessness continued, and he felt very ill. He was removed to hospital in the evening, by which time his legs were rapidly becoming paralysed. There was almost complete and permanent paralysis of all muscles of the lower limbs and severe weakness of abdominal and lower spinal muscles. The upper limbs were very slightly affected.

*Severe Spinal Pain Preceding Slight Paralysis*

Case 6 (25).—Housewife aged 30. Day 1:—Usual household duties. She felt very tired after a half-hour walk in the afternoon. In the evening she developed sacral pain and also a pain in the right lower abdomen when walking. Day 2:—She stayed in bed. The sacral pain became severe and caused great restlessness. Pain in the neck developed. Day 3:—After a sleepless night the sacral and cervical pains were severe. She vomited frequently in the evening, which necessitated her getting out of bed every half-hour or so. The restlessness also made her feel she would like to get up and move about. Day 4:—No change. Day 5:—Pains less severe, but there developed paresis of the trunk, left thigh, and left leg muscles. Satisfactory recovery occurred during convalescence in all the affected muscles.

TABLE I.—Analysis of the Spinal or Meningeal Pains as they Appeared in the 95 Cases which Reported these Pains during the Pre-paralytic Stage

Pains in	Head	Neck	Back (Lumbar or Dorsal)	Back (Sacral)	Shoulders or Scapular Region	Chest or Abdomen	Thighs or Legs
Head .. .. .	64						
Neck .. .. .		57					
Back (lumbar or dorsal) .. .			32	8	11	15	15
Back (sacral) .. .			27	10	9	12	15
Shoulders or scapular region .. .			52	11	7	12	18
Chest or abdomen .. .					4	9	11
Thighs or legs .. .				23	13	4	4
						24	15
							31

symptoms are common no one of them appears in more than two-thirds of the cases.

**Pains in the Head**

There is nothing specific about the headache when it occurs except that it is rarely intolerable, as it may be, for example, in meningitis: it may consist more of a soreness at the back of the head which is part of a spinal neck pain. Pain in the head appeared on the first day of the pre-paralytic stage in 45 of the 100 cases. In a few instances severe throbbing frontal pain was reported, but generally the headache was relatively insignificant. Study of the head pains may be of value in differential diagnosis, in that a patient who has spinal rigidity without severe headache is unlikely to be suffering from meningitis. Occa-

A history of *pain in the neck* is difficult to distinguish from stiffness, and the symptom is often more accurately described as a painful stiffness.

*Neck Pain in the Pre-paralytic Stage Causing Difficulty with Diagnosis*

*Case 7 (35).*—Male cinema operator aged 16. *Day 1*:—Slight headache in the morning. Work as usual. About 8 p.m. there developed aching pain in the neck which made him disinclined to move his head. *Day 2*:—After sleeping badly the pain in the neck continued; headache returned with some pain in the scapular region. Some vomiting and anorexia also occurred. He rested at home and went to a hospital out-patient department at 6 p.m. Here his neck and spine were examined at length, and he was told to return next day for x-ray examination. *Day 3*:—He visited hospital, where he was again examined at length, and finally the x-ray examination was cancelled, and a lumbar puncture established the diagnosis. He had now developed such sacral pains that he was unable to lie on his back. He was admitted to hospital that evening, and by then there was paresis of the trunk and left thigh.

Six weeks later there was still paralysis of the muscles supplied by the upper dorsal cord, especially the intercostals. The limbs were not affected.

*Neck Pain and Stiffness in Pre-paralytic Phase Followed by Paralysis of Neck Muscles*

*Case 8 (7).*—Schoolgirl aged 11. *Day 1*:—Developed pain and stiffness in neck, but felt quite well. *Days 2 and 3*:—Pain gradually became worse. She continued to attend school, but got into trouble for not working well. She was obliged to hold her neck stiffly. Her father rubbed her neck and wrapped it up with a scarf. *Day 4*:—Neck pain continued, also some fever, and she felt miserable. Attended school as usual. *Day 5*:—Stayed in bed, and this relieved the neck pain. *Day 6*:—Paralysis of neck muscles.

A month later there was almost complete paralysis of neck muscles; no weakness elsewhere.

**Pains in Chest, Abdomen, or Thighs**

Pains in the chest and abdomen may cause considerable diagnostic difficulty. Some characteristics which these pains may exhibit are apparent in the following records:

*Pain in Chest as the Principal Early Pre-paralytic Symptom*

*Case 9 (10).*—Male surveyor aged 43. *Day 1*:—Having suffered from a sore throat for the previous eight days, he now developed a girdle sensation around his chest, which became tender to touch. *Day 2*:—Chest pain continued, with fever, restlessness, and sleeplessness. *Day 3*:—Vomiting and anorexia also experienced. *Day 4*:—Pain in back and legs added to symptoms. Developed weakness of the right arm, trunk muscles, and right thigh.

Ten days later the muscular weakness was slight and recovering rapidly.

*Pain in Chest as an Early Pre-paralytic Symptom*

*Case 10 (34).*—A nurse, aged 21, who had been nursing cases of poliomyelitis (night duty) for a month. *Day 1*:—About mid-day she developed bilateral chest pain, which was aggravated by a deep breath and was associated with hyperaesthesia: she could not bear the touch of bedclothes on her chest. She went on duty in the evening, but was sent to bed about 10 p.m. *Day 2*:—Chest pain ceased and was replaced by severe frontal aching pain in the head and later by severe sacral pain, both of which continued for three weeks after paresis developed. *Day 3*:—Pain in the front of thighs on moving. *Day 4*:—Neck stiff. Weakness developed in left arm, trunk, left thigh, and left leg.

All the affected muscles recovered well within two months.

*Severe Abdominal Pain as a Pre-paralytic Symptom*

*Case 11 (15).*—Schoolgirl aged 10. *Day 1*:—Sent home from school with sore throat, fever, and headache. Went to bed. *Day 3*:—Felt well. *Day 4*:—Got up, but was put to bed again

on *Day 5* as she looked tired. *Day 6*:—Pains in thighs and back. *Day 8*:—Developed unbearable pain in lower abdomen, back, and thighs. Rolling about in agony. Severe vomiting. *Day 9*:—Pains abated. Weakness of thighs and legs appeared, but this was not severe, and had largely recovered within three weeks.

*Pain in Trunk on Movement as a Pre-paralytic Symptom*

*Case 12 (3).*—Male machinist aged 25. *Day 1*:—Slight stiffness in back and pain in the head. Did a heavy day's work. *Day 2*:—Ditto. *Day 3*:—Headache worse, and severe pain developed in thighs and a sharp pain in the left side of the chest each time he stepped forward with the left leg. Left leg also ached. *Day 4*:—Vomiting added to the above symptoms. Weakness of abdominal muscles developed. *Day 5*:—Pains ceased, but weakness spread to the thighs and legs.

A month later the left quadriceps was completely paralysed; all the other muscles affected were improving.

*Discomfort in Chest and Abdominal Pain as Pre-paralytic Symptoms*

*Case 13 (44).*—Schoolboy aged 16. *Day 1*:—Feeling of constriction in the chest on taking a deep breath. Ran 100 yds. race. *Day 2*:—Pain in right iliac region on bending while playing a rackets match. *Day 3*:—Above symptoms continued. Some malaise. Ran a half-mile race not so well as he expected. *Day 4*:—Severe headache and pain in neck developed; fever, restlessness, and sleeplessness. School in morning. Tennis for half an hour; then reported sick for the first time and was sent to bed. That night he developed rapidly spreading severe paralysis, especially of lower limbs and trunk. A respirator was required for two weeks.

The permanent disability in this case was severe.

*Pain in Thighs as a Pre-paralytic Symptom*

*Case 14 (48).*—Accountant aged 27. *Days 1-4*:—Malaise and slight fever. *Day 5*:—Office work as usual. Slight sore throat; temperature normal. At night developed severe pains in both thighs. Walked about for some hours at night to get relief. *Day 6*:—Thigh pains ceased. Temperature 102° F. (38.9° C.). Visited a friend and had difficulty in climbing stairs. Cycled one mile. Sat in a chair for some hours talking to a friend while his legs were gradually becoming paralysed. *Day 7*:—Stayed in bed. By the evening he was completely paralysed from the chest downwards, and this complete paralysis of the lower limbs was permanent.

*Spinal Paraesthesia as an Early Symptom*

*Case 15 (45).*—Female clerk aged 29. *Day 1*:—Nasal catarrh for past six days. Now developed pain in the back of the neck and a sensation like "cold water running down the spine." Work in office as usual. *Day 2*:—Same symptoms, with vomiting and fever in addition. Rest at home, but she went out to visit doctor. *Day 3*:—Symptoms less severe; resting at home. *Day 4*:—Felt well; no pain now, but weakness of left arm developed.

A month later the left deltoid was still completely paralysed, but other affected muscles were recovering slowly.

**Other Pre-paralytic Symptoms**

Vertigo and a visual abnormality due to jerky movements of the eyes may appear early in the pre-paralytic phase when, as Bodian (1948) has shown, the virus is already in the brain-stem. Vomiting is common but seldom severe. It was reported in 29 of the 100 cases.

Nasal discharge, sore throat, diarrhoea, or constipation may occur in the pre-paralytic phase, but, being non-specific, these symptoms are usually of little value in early diagnosis.

**Phases in the Pre-paralytic Stage**

Several variations in the course of the disease occur which are most easily described by brief case reports. In some

instances it is difficult to ascertain whether or not the prodromal stage is merging with the pre-paralytic stage.

In the pre-paralytic stage of "typical" cases spinal symptoms usually become increasingly severe for two or three days, after which time paralysis appears and the spinal symptoms often subside quickly. In some cases, however, the course of the pre-paralytic stage is erratic and may consist of two or more phases, as in the following examples.

*Case 16 (68).*—Schoolboy, aged 12, attending a scout camp. *Day 1:*—Frontal headache and a pain over the anterior aspects of both thighs—"like a wire brush being pressed into the flesh." Tired and sleepy. *Days 2 and 3:*—Felt well, but noticed that running about brought back the pain in his head and thighs. Took part in all camp activities. *Day 4:*—Returned home, but still felt unusually tired. Average physical activity. *Day 7:*—Severe pains developed in head, thighs, and knees. He went to bed early, but was wakened at 9 p.m. by a nightmare to find the pains were worse than ever, and there was also abdominal pain. *Day 8:*—Pains continued. Vomiting, retention of urine, and fever—101.4° F. (38.55° C.). Severe paralysis of the left leg and thigh developed.

*Case 17 (6).*—Schoolboy aged 12. *Day 1:*—Pain in back of neck and back of knees; malaise and shivery feeling. Fever about 101° F. (38.3° C.). In bed for two days. *Day 3:*—Got up, but pyrexia returned. Returned to bed, where he remained for four days. *Days 10-14:*—Living very quietly at home. *Day 16:*—Resumed school. *Day 18:*—Played rugby football match. *Day 19 (evening):*—Headache and slight vomiting. Temperature 100° F. (37.8° C.). Went to bed. *Day 20:*—Developed pain in back of neck. *Day 21:*—Pains worse; also pain in dorsal spine. Girdle hyperalgesia and retention of urine. The cerebrospinal fluid contained 502 polymorphs, 280 lymphocytes, and 14 endothelial cells per c.mm., and there was 80 mg. of protein per 100 ml. *Day 22:*—Symptoms subsided. Temperature became normal, and no paralysis developed.

*Case 18 (79).*—Housewife, aged 30, two months pregnant. *Day 1:*—Mild neck stiffness. *Days 2-4:*—Felt well; usual housework. *Day 5:*—Lumbo-sacral pain and worsening of vomiting of pregnancy. *Days 6 and 7:*—Felt better, though vomiting continued. *Day 8:*—Lumbo-sacral pain recurred with greater severity, and there was also pain and stiffness of the neck and pains in both lower limbs. Temperature about 100.4° F. (38° C.). *Day 9:*—Symptoms continued. *Day 10:*—Cerebrospinal fluid contained 124 polymorphs and 117 lymphocytes per c.mm. and 75 mg. of protein per 100 ml. *Day 11:*—Paralysis of lower limbs, trunk, and diaphragm. Respirator required.

This patient died later of pulmonary collapse.

#### *Spread of Paralysis in Two Phases*

*Case 19 (1).*—Housewife aged 33. *Day 1:*—Developed neck pain in the evening. *Day 2:*—Pains also in both shoulders. Some housework. *Day 3:*—Pains worse. Severe headache, restlessness, sleeplessness, and fever. Got up and went to see doctor. *Days 4 and 5:*—Symptoms continued. *Day 6:*—Paralysis of right shoulder and arm. Symptoms subsided. *Days 7 and 8:*—Felt well, but was restless. *Day 9:*—Improvement continued. Got up to have bed made; malaise and vomiting that evening. *Day 10:*—Paralysis spread to involve right thigh, right leg, and right intercostal muscles.

Another remarkable feature of the pre-paralytic stage occasionally observed is that the patient's symptoms may appear to be abating at the time the paralysis develops.

#### *Abrupt Onset of Pre-paralytic Phase, Symptoms Subjectively Subsiding when Paralysis of Nearly all Muscles Developed*

*Case 20 (29).*—Female factory-worker aged 21. *Day 1:*—Wakened with pain in the neck, back, and head. Worked all day in the factory; the journey to work involved travelling for an hour each way. She vomited and noticed something peculiar about her eyes: she thought she might be getting infantile paralysis. *Day 2:*—Slept well but still had pain in the neck, back, and head. She got up and walked (15 minutes) to see her doctor, who told her she had a chill, so she returned

home, went to bed, and took castor oil. *Day 3:*—Pains less severe. She remained in bed, and felt rather better. In the evening some friends called, and she sat up in bed talking to them for four hours (6 to 10 p.m.). Within an hour of her friends' leaving she noticed weakness of her limbs. *Day 4:*—By early morning she was totally paralysed and her respirations were failing; when she reached hospital she was severely cyanosed and was at once placed in a respirator. Ten weeks later there was very little recovery, and she was still unable to breathe without the respirator.

Thieffry (1947) has also drawn attention recently to paralysis occurring in some cases after the fever of the pre-paralytic stage has returned to normal.

#### **Atypical Cases**

The cases which show no definite onset of the spinal or meningeal symptoms may be conveniently termed "atypical" cases. There were 11 of this type among the 100 cases studied here. The onset of the pre-paralytic phase may appear indefinite when prodromal catarrhal symptoms merge into the spinal symptoms without the usual interval—see Case 9. The day of onset is also uncertain when the spinal symptoms are at first vague (see Cases 4 and 13), or they may continue for so many days before paralysis develops that the pattern of the disease is altered.

#### *Prolonged Pre-paralytic Stage with Indefinite Onset*

*Case 21 (41).*—Housewife aged 28. *Days 1 and 2:*—Tenderness of lower ribs for two days; no pain. *Days 3 and 4:*—Tenderness of upper abdomen for two days; no pain. *Days 5-7:*—Tenderness of lumbar spine for three days. Very light work. *Day 8:*—Tender on the anterior aspect of the right leg for two days. Very light work. *Day 9:*—In the morning sacral pain and stiffness developed. In the evening slight jerks of the right leg occurred with some pain in the leg. *Days 10 and 11:*—Sacral pain continued and slight fever developed.

The sacral pain continued until *Day 17*. The neck was stiff on admission to hospital on *Day 13*. On *Day 15* the cerebrospinal fluid contained 115 cells per c.mm. (10% polymorphs) and 70 mg. of protein per 100 ml. No paralysis developed except perhaps a transient slight paresis of the right leg.

*Case 22 (77).*—General practitioner aged 38. *Day 1:*—Malaise and headache in the evening. *Day 2:*—Rested at home. *Day 3:*—Listless and shivery; resumed practice. *Day 4:*—No change. *Day 5:*—Strenuous walk over the hills to "shake off" his malaise. *Days 6 and 7:*—Continued his practice, though symptoms persisted. *Day 8:*—Forced to go to bed with fever, severe frontal headache, and pain and stiffness of the neck. *Day 9:*—Excruciating sacral pain added to symptoms. *Day 10:*—Weakness of right arm and leg and, later, respiration. *Day 11:*—Respirator required; nearly all muscles paralysed. *Day 12:*—Died.

#### **Discussion of Stages and Phases**

Examination of these widely varying case records leads to certain conclusions. (1) Prodromal symptoms are usually non-specific, but sometimes they include spinal symptoms of a type suggesting that the virus is already in the spinal cord. (2) The symptoms of the pre-paralytic stage usually begin abruptly, get worse for 2, 3, or more days, and culminate in paralysis. Subjectively the patient may feel better when paralysis develops. (3) During the pre-paralytic stage the symptoms may abate and the patient feel that he has recovered from the illness, though the symptoms recur more violently and lead to paralysis. (4) Occasionally the paralysis may appear in two distinct phases, with an interval of several days between the first and second. (5) When there are two or more phases to the pre-paralytic stage each phase usually has spinal symptoms of the same type as occur in cases with only one pre-paralytic phase.

The pre-paralytic stage of poliomyelitis is therefore a highly critical time for the patient. Here the battle with

the invading virus reaches its climax. The amount of spinal cord damage must to a large extent be determined at this stage before paralysis actually supervenes. There is clinical evidence from the occurrence of spinal symptoms that in some cases this struggle is already being fought within the central nervous system during the prodromal stage. Experimental studies support this possibility, as Horstmann (1948) has pointed out.

The two or more phases which may occur in the pre-paralytic stage suggest that the body may appear to conquer its foe, but after apparent victory something "goes wrong"; the virus triumphs at the second assault and paralysis results. The sudden triumph by the virus and its simultaneous appearance throughout nearly all parts of the spinal cord and brain-stem is a puzzling feature of experimental poliomyelitis.

According to Bodian (1948) the virus reaches its maximum concentration in the spinal cord twenty-four hours before paralysis, and as the paralysis is advancing the concentration of the virus drops rapidly. Experimental infections do not, however, often run a biphasic course, and one can only speculate on the likely concentrations of virus in the spinal cord at the various stages of a human case with a biphasic pre-paralytic stage.

**Effect of Physical Activity on Motor Neurone Vulnerability to the Virus**

In the literature of poliomyelitis there are many reports regarding cases in which violent physical exertion appeared to precipitate a severe or fatal paralysis or in which the muscles specially exercised were those most paralysed. Reference to these cases is made by Levinson *et al.* (1945), who have also made observations on the effect of fatigue and cold in increasing the amount of paralysis in monkeys infected with the virus.

In a preliminary report on the present study (Russell, 1947) the effect of exercise upon the final paralysis was examined statistically, and it was shown that the continuance of even moderate physical activity in the pre-paralytic stage is dangerous. Hargreaves (1948) has to a large extent confirmed these observations.

If physical activity has this important influence on the course of the disease it might show its influence in one of three ways: (1) Physical activity might bring on the acute pre-paralytic phase in a patient who would otherwise have an abortive attack with no more than prodromal symptoms or perhaps no noticeable symptoms at all. (2) Physical activity after the onset of pre-paralytic symptoms might increase the risk or indeed determine the amount and site of paralysis. (3) Physical activity after the subsidence of a first phase of the pre-paralytic stage might lead to a recurrence of the meningeal symptoms and thus increase the danger of paralysis.

**Excessive Physical Activity Preceding Pre-paralytic Stage**

With regard to the first of these possibilities a study of the case records suggests that excessive physical activity may sometimes play a part in deciding the onset of the dangerous pre-paralytic stage. The evidence of this consists merely in a history of extra physical activity within twenty-four hours of the onset of the pre-paralytic stage in 17 of the 100 cases.

The correlation of physical activity with this particular aspect of the disease is difficult to handle statistically, but the following cases certainly suggest that violent physical exertion may sometimes be a factor which determines that a prodromal illness or latent infection will not remain abortive but will develop the spinal symptoms of the pre-paralytic stage with the consequent danger of paralysis.

This possible effect of physical activity in precipitating the pre-paralytic stage of the disease must be clearly distinguished from the effect of physical activity *during* the pre-paralytic stage on the severity of paralysis. This latter aspect can be handled with confidence statistically, and will be referred to later.

*Special Physical Activity in Prodromal Stage Followed Within 24 Hours by Acute Spinal Symptoms and Later by Paralysis*

*Case 23 (89).*—Airman aged 33. *Day 1:*—Headache and sore throat; off duty for one day. *Days 2-6:*—Felt well. *Day 7:*—After usual work played rugby football. *Day 8:*—Severe pain in spine and chest with fever. Continued work. *Day 9:*—Severe paralysis of all muscles of the lower limbs and lower trunk.

*Case 24 (91).*—Airman aged 22. *Days 1 and 2:*—Sore throat and headache. Quiet days on board ship. *Day 3:*—Ashore walking round all day. In evening developed sacral pain. *Day 7:*—Paralysis of abdominal muscles and thighs.

*Case 25 (84).*—Airman aged 23. *Day 1:*—Cold in head and sore throat for two days. *Days 3-9:*—Tired, but weather very hot. *Day 10:*—Very hard badminton match. In evening developed fever and pain in head and neck. *Day 13:*—Severe paralysis of both upper limbs.

*Case 26 (71).*—Schoolboy aged 14. Had cold for three or four days. A week later he played rugby football, and on the night following developed pain in the back and a few days later slight abdominal paralysis.

There are four further examples of this type among the group of "typical" cases with prodromal symptoms.

There are also nine among the "typical" cases *without* prodromal symptoms in which the pre-paralytic stage with spinal symptoms was immediately (within two to twenty-four hours) preceded by some special physical activity as in the following examples.

*Special Physical Activity Immediately Preceding Spinal Symptoms in "Typical" Cases with No Reported Prodromal Symptoms*

*Case 3 (28).*—Male aged 12. Football six hours before onset. *Case 19 (1).*—Female aged 33. Six hours spent washing for a school, extra to usual work, eight hours before onset.

*Case 27 (4).*—Male aged 13. Long run (several miles) soon after beginning of school term, sixteen hours before onset.

*Case 28 (86).*—Male aged 22. Tennis tournament all day twenty-four hours before onset. Yachting six hours before onset.

*Case 29 (94).*—Male aged 21. Tennis tournament twenty-four hours before onset.

*Case 30 (90).*—Male aged 28. Playing squash-rackets three hours before onset.

**Physical Activity During the Pre-paralytic Phase and its Influence on the Severity of Paralysis**

In order to correlate the possible effect of physical activity during the pre-paralytic stage with the severity of paralysis a method of scoring has been used for both the amount of physical activity and the severity of paralysis (Russell, 1947).

In Table II the days of the disease are numbered backwards from the day paralysis appeared (P-1, P-2, P-3,

TABLE II.—Physical Activity on the Days Preceding Paralysis Compared in Cases Developing (1) Slight, (2) Moderate or Severe Paralysis

Severity of Paralysis	No. of Patients in Each Group who Undertook Moderate or Severe Physical Activity During Each of the Four Days Preceding Paralysis (P-1, P-2, P-3, P-4)			
	P-1	P-2	P-3	P-4
Slight (33 cases)	0	6 (18%)	11 (33%)	18 (54%)
Moderate or severe (59 cases)	14 (23%)	35 (59%)	51 (86%)	53 (90%)

and P-4). The cases are divided into two groups: (1) slight paralysis—good recovery expected; (2) moderate or severe paralysis—permanent disability expected. The proportion of cases in each group which continued physical activity during these four days is shown. It is obvious that non-paralytic cases cannot be included in this table.

Another method of investigating this matter is by numbering the days of the disease from the onset of the pre-paralytic stage; but this can only be done in the "typical" cases with an abrupt onset of spinal symptoms. In Table III

TABLE III.—Comparison, in "Typical" Cases Only, Between the Severity of Paralysis and the Amount of Physical Activity after the Onset of the Pre-paralytic Stage

Amount of Physical Activity After Onset of Pre-paralytic Stage	Permanent Paralysis		
	Slight or None	Moderate	Severe or Fatal
Nil or slight for less than 24 hours	30	6	2
Moderate or severe for less than 24 hours	6	9	7
Slight, moderate, or severe for more than 24 hours	2	12	15
Totals	38	27	24

the ultimate severity of paralysis in the typical cases is compared with the amount of exercise continued after the start of the pre-paralytic stage.

Both Tables I and II show a remarkable and highly significant increase of severe paralysis in association with a continuance of physical activity in the days preceding paralysis.

The question naturally arises why certain patients continue average or severe activities after the onset of symptoms. As has already been emphasized, these symptoms may be quite slight, but there is certainly no evidence to suggest that those patients destined for severe paralysis have less disturbing pre-paralytic symptoms than have the slight cases. The question cannot be answered with great confidence, but my impression is that often those who continue physical activity after the symptoms begin either are relatively insensitive to pain or have more than the average courage or incentive to continue work or play in spite of illness. There is certainly no doubt that many of those most severely crippled have a remarkable strength of character and great powers of endurance. It has been said that the disease picks out the best child of the family.

Many young children pay little attention to bodily pains, and this may explain an apparent absence of spinal pain in some infants developing poliomyelitis.

### The Effect of Trauma

There are a few reported cases of poliomyelitis in which local trauma appeared to determine the site of maximum paralysis (see Levinson *et al.*, 1945). In such a case, for example, poliomyelitis occurring soon after an arm fracture would lead to paralysis affecting chiefly the fractured arm. This type of case, infrequent though it is, raises the possibility either that peripheral trauma provides the virus with easy access to the neurones or that it modifies the physiology of the spinal cord cells of the segments concerned in such a way as to make them more vulnerable to the virus.

Experimental studies on these lines provide much food for thought. Hurst (1930) found that injection of the virus into the sciatic nerve led to paralysis beginning in the same leg only if the nerve is deliberately injured by the injecting needle. In such an experiment the paralysis develops without the preceding fever noticed in other forms of experimental infection (e.g., intracerebral). Infection was prevented if the injected nerve was excised within twenty-

four hours of injection. Howe and Bodian (1942) found that section of nerve roots some days before infection protected the corresponding nerve cells from attack by the virus. German and Trask (1938) injected virus into denervated skin caused by section of anterior and posterior roots, denervation of a skin flap, or denervation of a whole lower limb from the mid-thigh level. They found that not only did the disease caused by injection into denervated skin develop with the normal pattern, but that the animals infected after these operations were more vulnerable and developed more severe paralysis than the controls. The limbs on the side of the operation were usually affected first. From these experiments it was clear that, though the virus did not have any nerves along which to travel, it reached the spinal cord just as quickly as in the controls, and apparently found that the previous operations had increased the vulnerability of the spinal cord cells in the appropriate segments.

These observations necessitate reconsideration of the theory that the virus travels principally via the neurones. This theory is based on a number of studies. Hurst's work on the sciatic nerve has just been referred to. In the tragic accidents with poliomyelitis "vaccine" reported by Leake (1935) the arm inoculated was always the first to be paralysed. After intracerebral inoculation of the virus paralysis appears first in the contralateral limbs (Jungeblut and Spring, 1930).

Though these observations are generally held to indicate neuronal transmission of the virus, it is also possible that this pattern of spread is due not to the trauma providing neuronal access but to the trauma modifying the physiology and increasing the vulnerability of the spinal cord cells with which the traumatized area is in anatomical neuronal connexion.

The following case records may be relevant to this problem.

#### T.A.B. Inoculation on Right Arm. Acute Illness 7 Days Later. Paralysis of Right Arm

Case 31 (12).—A newly conscripted soldier aged 18. Day 1:—A T.A.B. inoculation was given by subcutaneous injection on the outer side of the right upper arm. The arm was stiff for two days, but he did not feel well during the week following, so he rested most of the time. Day 7:—In the evening a painful stiffness of the neck and scapular region developed. There was also anorexia. Day 8:—Headache and fever (103° F.=39.4° C.) were added to symptoms. Day 9:—The cerebrospinal fluid contained 133 white cells per c.mm. and 75 mg. of protein per 100 ml. Day 10:—Paralysis of right deltoid, biceps, and triceps. No other muscles were affected.

#### Severe Paralysis of Lower Limbs and Trunk 10 Days After Several Intramuscular Injections in Buttocks

Case 32 (101).—Schoolgirl aged 10. Day 1:—Severe earache, for which she was given intramuscular injections of penicillin into the buttocks every four hours for three days. Day 8:—Felt tired and had a slight headache on waking. Though her temperature was normal at lunch-time it was raised a little by the evening. Slight activity during the forenoon; then went to bed. Day 9:—Slight sore throat added to symptoms. In bed all day. Day 10:—Felt quite well. In bed all day except that she got up to motor home—one hour's run. Day 11:—Developed moderately severe pains in both thighs. In bed all day. Day 12:—Severe paralysis of both lower limbs and lower trunk muscles. This was still very severe two months later.

(Her brother also had pains in the thighs at about the same time, but did not develop paralysis.)

If these two examples record anything more than a remarkable coincidence then they suggest that at a certain early stage of virus infection even the trauma of an

injection will increase the vulnerability of that part of the spinal cord which supplies the site of injection. The well-recognized effect of tonsillectomy on increasing the liability to bulbar palsy may act in the same way (Horstmann, 1948).

**Type of Physical Activity Related to Site of Paralysis**

There have been many reported instances of the paralysis of poliomyelitis being worse in those muscles which were most exercised at the onset of the illness. Table IV gives

TABLE IV.—Poliomyelitis. Comparison Between Type of Exercise and Permanent Paralysis

Case No.	Day of Exercise in Relation to Day of Onset of Pre-paralytic Stage (D) and to Day of Paralysis (P)		Type of Exercise	Site and Severity of Paralysis (Slight +, Moderate ++, Severe +++)
	D	P		
13 (44)	3	-1	Half-mile race	Lower limbs +++ Trunk +++
4 (39)	-1	-3	Four-mile race	Lower limbs +++ L. arm ++
(52)	1	-1	Schoolboy playing organ for 1 hour. R. leg: special strain	R. leg and thigh only +++
70)	1	-1	Throwing chain with R. arm (surveyor)	R. upper limb +++ L. leg ++
(51)	3	-1	Severe asthma	Abdomen +++ Intercostals +++ R. shoulder ++ R. thigh ++
(83)	1	-3	Playing piano for 1½ hours. R. hand: special strain in the piece played	R. arm and hand only +++
17 (6)	1, 2, 3	-2, -1	Milkman—on feet all day	Trunk and thighs +++ L. leg +
(36)	1 to 7	-7 to -1	Heavy-truck driving	Both lower limbs +++
(9)	1, 2	-1, -2	Heavy training: carrying machine-guns uphill 6 hours before paralysis	Universal severe paralysis; respirator; died 3 months later

Cases in which the muscles used most during the pre-paralytic stage were most severely paralysed.

several examples of this correlation between the type of physical activity and the site of maximum paralysis, and thus provides further evidence regarding the harmful effect of physical activity.

**Conclusions**

These observations help to consolidate views held by many experienced physicians: first, that the pre-paralytic stage of poliomyelitis, though variable, can often be recognized correctly; and, secondly, that physical activity at the onset of the disease is dangerous.

The tables which illustrate this paper indicate that complete physical quiet from the onset of symptoms will seldom fail to prevent serious paralysis, while strenuous or even moderate physical activity at this stage is highly dangerous. On theoretical grounds, therefore, it should be possible to prevent many of the grave cases which occur. For example, those who have the care of children, especially at holiday camps and schools, should learn of the ways in which the disease can present. Sports meetings and special athletic contests should, if possible, be held outside the season for poliomyelitis. During an epidemic physical activity should not be exhausting, and should be avoided entirely during minor illnesses. The dangerous idea that symptoms may be "worked off" by exercise should be countered emphatically.

During the acute stage of the disease perhaps the chief aim in treatment should be to maintain for the patient a state of mental and physical quiet. He should be surrounded by an atmosphere of calm and confident efficiency. Sedatives and analgesics are often essential, but little information is available on what are the best sedatives to use in this disease. Probably all sedatives are safe in moderate doses, but patients in the acute stage of the disease must,

especially if on sedative treatment, be watched carefully lest respiratory paralysis develop during sleep.

The not uncommon need to rest the muscles of respiration should be kept in mind. Slight respiratory weakness leads to alarm and sleeplessness. Weakness of coughing is an early sign. This can often be relieved by using the artificial respirator for a short time, but in mild cases a lung inflator is particularly valuable, and is less worrying to the patient. A lung inflator\* can be used to give highly effective artificial respiration for a period of hours if necessary, and should be at hand in all cases of paralytic poliomyelitis during the acute stage of the disease. In respirator cases a lung inflator is especially valuable, as it enables artificial respiration to be fully maintained when the patient is removed from the respirator for nursing and other purposes.

**Summary**

In 100 cases of poliomyelitis the early symptoms have been studied in detail.

The prodromal stage, when present, consists usually of a brief non-specific illness, but neurological symptoms occasionally appear even at this early stage.

The pre-paralytic stage is the most critical period of the disease. Spinal symptoms in "typical" cases begin abruptly, and occurred in 95 of the 100 cases. They are of great value in diagnosis, but are very variable as regards both type and severity.

Two or more phases of the pre-paralytic stage may appear, and paralysis may spread in two or more stages. The spinal symptoms may subside before paralysis develops.

In "atypical" cases the onset of the pre-paralytic stage is vague, and the symptoms of a prodromal stage may appear to merge into the pre-paralytic stage.

An unusual amount of physical activity immediately preceded the pre-paralytic stage in 14 of the 100 cases.

Complete physical rest in bed from the onset of the pre-paralytic stage greatly reduces the danger of severe paralysis. Severe physical activity at this stage is almost suicidal, while the continuance of even average physical activity is dangerous.

The possible effect of trauma in localizing the disease is considered.

During an epidemic physical activity should be avoided entirely in minor illnesses. The highly dangerous belief that malaise and other vague symptoms should be "worked off" by exercise requires correction.

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\*The Oxford inflator (Medical and Industrial Equipment, Ltd.) as described in the *Lancet*, 1939, **1**, 206.