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Historical Reviews

Contribution of Jules Froment to the Study of Parkinsonian Rigidity

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Abstract: Rigidity is commonly defined as a resistance to passive movement. In Parkinson's disease (PD), two types of rigidity are classically recognized which may coexist, "leadpipe " and "cogwheel". Charcot was the first to investigate parkinsonian rigidity during the second half of the nineteenth century, whereas Negro and Moyer described cogwheel rigidity at the beginning of the twentieth century. Jules Froment, a French neurologist from Lyon, contributed to the study of parkinsonian rigidity during the 1920s. He investigated rigidity of the wrist at rest in a sitting position as well as in stable and unstable standing postures, both clinically and with physiological recordings using a myograph. With Gardère, Froment described enhanced resistance to passive movements of a limb about a joint that can be detected specifically when there is a voluntary action of another contralateral body part. This has been designated in the literature as the "Froment's maneuver " and the activation or facilitation test. In addition, Froment showed that parkinsonian rigidity diminishes, vanishes, or enhances depending on the static posture of the body. He proposed that in PD "maintenance stabilization " of the body is impaired and that "reactive stabilization " becomes the operative mode of muscular tone control. He considered "rigidification " as compensatory against the forces of gravity. Froment also demonstrated that parkinsonian rigidity increases during the Romberg test, gaze deviation, and oriented attention. In their number, breadth, and originality, Froment's contributions to the study of parkinsonian rigidity remain currently relevant to clinical and neurophysiological issues of PD.

Key words: Jules Foment; history; Parkinson's disease; rigidity; cogwheel phenomenon; Froment activation maneuver.

INTRODUCTION

Rigidity is commonly defined as a continuous and uniform increase in muscle tone felt as constant resistance to passive movement. This classically refers to extrapyramidal suyndromes and must be differentiated from other forms of hypertonicity including spasticity (spastic rigidity of hemiplegic patients) where the increase in muscle tone is velocity-dependant and more pronounced in extension than flexion, and from *gegenhalten*, where the patient is not fully relaxed or is opposing the movement.[1,2] In Parkinson's disease (PD), two types of parkinsonian rigidity are classically recognized and may coexist. In the "leadpipe " rigidity ("rigidité en tuyau de plomb " in French literature), rigidity is uniform throughout the entire range of movement at any joint, in both extension and flexion. Further, it is increasingly severe with advanced disease. In "cog-wheel " (or cogwheel) rigidity ("roue dentée " in French literature), the hypertonicity is regularly interrupted at a 4 to 6 Hz frequency, corresponding to the frequency of resting tremor, and sometimes at 8 to 9 Hz frequency which is close to the frequency of postural tremor.[2,3] It is often associated with

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tremor and may be detected clinically at early stages of PD. Full recognition and description of parkinsonian rigidity was made by several eminent neurologists over a long period of time. Parkinson himself did not pay attention to rigidity in his seminal work from 1817, but rigidity was clearly recognized by Charcot in the second half of the nineteenth century.[4] The cogwheel phenomenon per se was identified only several decades later at the beginning of the twentieth century by Camillo Negro in Turin, Italy, and Harold N. Moyer in Chicago, USA.[5-7] A recent review emphasizes the major contribution of these two authors as well as that of Robert Novoa Santos in Santiago, Spain,[8] all three being apparently unaware of each other's work.[9]

This study focuses on further extensive clinical and neurophysiological studies on parkinsonian cogwheel rigidity performed during the 1920s by Jules Froment, one of the distinguished French neurologists of the first half of the twentieth century. Within a few years, Froment's work became well recognized in French-speaking medical journals and textbooks, and his techniques were widely applied to the clinical examination of parkinsonian patients in daily practice. Outside of French-speaking circles, however, his important descriptions are infrequently referenced in studies of parkinsonian rigidity. Notably, the "Froment maneuver", which facilitates the detection of rigidity with volitional activation of the contralateral limb, is widely known internationally but without attribution to Froment's original description.

JULES FROMENT, THE NEUROLOGIST

Jules Froment (1878–1946) (Fig. 1) studied medicine in Lyon, France, where he became intern then consultant.[10,11] During World War I, Froment went to Paris where he worked with Joseph Babinski at the Pitié-Salpêtrière Hospital. He focused his early interest on peripheral nerve palsies in war-injured patients. In 1915, Froment described the classical "Froment's newspaper sign", or "Froment's thumb sign" ("signe du journal" in French), which is still used to diagnose ulnar nerve palsies.[12,13] Briefly, the deep palmar branch of the ulnar nerve at the wrist is motor and its damage will cause weakness of the inteossei, particularly the first, and of adductor pollicis. As a result, a flat object as a newspaper cannot be held firmly between thumb and radial border of index despite compensatory flexion of the terminal thumb phalanx: This is known as Froment's sign. One of Froment's major works with Babinski focused on hysteria, pithiatism, and sympathetic reflex nervous disorders in the context of war-related trauma, also known as the physiopathic syndrome or the Babinski-Froment syndrome.[14,15] Froment returned to Lyon in 1918, where he became chief of a Department of Medicine, and later Professor of Medicine. He made many other contributions to neurology, notably concerning language and speech disorders, gait, and above all on parkinsonism.[10,11]

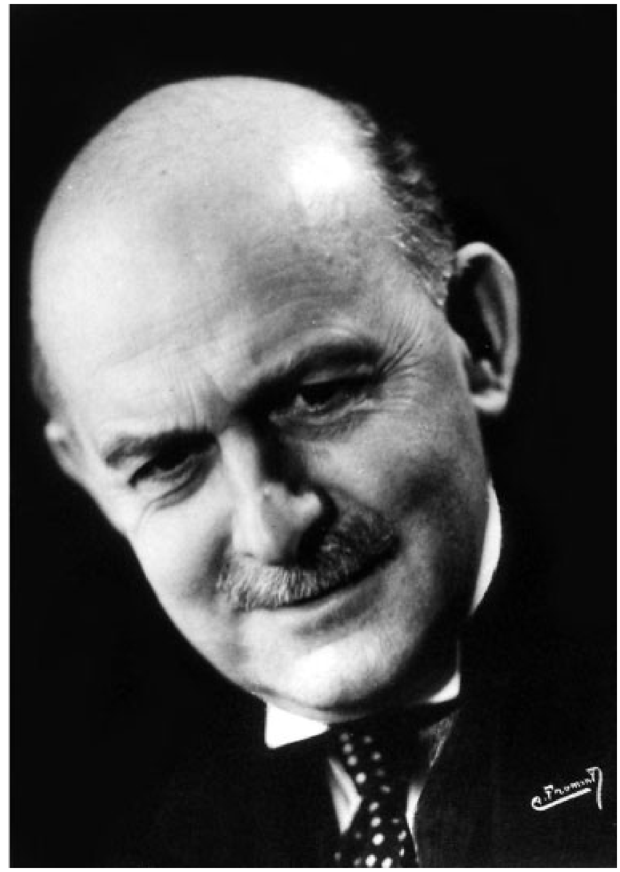

FIG. 1. Photograph of Jules Froment in the 1930s. Courtesy of Musée des Hospices Civils de Lyon.

During the 1920s, Froment invested his primary research effort specifically to the detailed clinical analysis of resting tremor and rigidity observed in PD but also in post-encephalitic parkinsonian syndromes. These latter cases were frequently encountered during the 1920s because of the epidemic of Von Economo encephalitis. His studies resulted in a large series of important scientific communications primarily presented at the Paris Neurological Society and published thereafter in *Revue Neurologique*[16-26] and as short communications in American neurological literature.[27,28]

FROMENT'S INVESTIGATION OF PARKINSONIAN RIGIDITY: A SCIENTIFIC APPROACH

From Dysbasia Lordotica to Parkinsonian Rigidity: The Role of the Static Posture of the Body

Froment was particularly interested in the physiological mechanisms related to human erect posture and gait, both in normal conditions and in neurological diseases. He began his research with cases of parkinsonism and dysbasia lordotica,[16] a form of generalized dystonia first described by Oppenheim. In such patients, the disturbed posture and increased muscular tone were apparent only on standing, but disappeared when patients were lying in bed. Could this abnormal posture and increased axial muscular tone reflect disturbed standing stabilization mechanisms and express the physiological basis of what he called the "static law " ("logique statique " in French) or law of gravity? Consequently, Froment raised the question as to whether increased muscular tone seen in parkinsonian patients with flexed posture and gait disturbances could depend on perturbations of the same static law. More specifically, could parkinsonian rigidity vary with the conditions of the neurological examination (rest, seated, lying on bed)? Indeed, Froment was aware of the cogwheel phenomenon that he called the Negro-Moyer phenomenon,[23] and had noticed that rigidity actually varied from one moment to another within a few minutes or even seconds in the same patient. To answer these fundamental questions, and as explained in a review of his experiments conducted in 1926,[23] Froment used a systematic and stepwise approach to understand the physiological laws underlying parkinsonian rigidity.

Clinical Experimental Conditions: The Use of a Comfortable Armchair and the Study of Rigidity at the Wrists

Froment hypothesized that parkinsonian rigidity could vary with changes in body posture.[23] To conduct his experiments, Froment studied muscular tone in different postures so as to induce varying antigravity forces. He first investigated several conditions where antigravity forces could be suppressed or markedly diminished, as floating in a swimming pool, lying in a steam bath (hammam) or in a bathtub at 40°C.[22,23] A more practical posture for laboratory study was the seated position in a comfortable armchair (Morris chair or "fauteuil colonial " in French), where all the parts of the subject's body including the head were completely supported. In this setting, there was no need for antigravity contraction as the limb was supported (the support providing the resistance to gravity).

Froment chose to focus on the examination of wrist muscular tone, where changes were easier to detect[23] than those at the elbow or lower limbs as initially described by Negro and by Moyer.[5-7] He applied slow and alternating passive flexion and extension movements at a variable frequency. He reasoned that, in patients comfortably seated in the armchair, passive movement of the wrist would not disturb general posture of the body and would produce less effect on muscular tone and arm posture compared to movements induced at the elbow.

Parkinsonian Rigidity Diminishes, Vanishes, or Reinforces Depending on the Static Posture of the Body

Froment and Gardère showed that the use of a comfortable armchair could diminish parkinsonian rigidity.[17] In this ideal resting position, they found that moderate rigidity and the cogwheel phenomenon of the wrist detected in other body positions were no longer detectable. However, if the patient moved slightly, for example, if he lifted his head up from the chair support, those two phenomena immediately reappeared. Froment and Gardère concluded that changes in trunkal posture directly affected muscle tone and that a primary element of PD was a dysregulation of normal static mechanisms.[17]

"The Froment Maneuver"

Froment and Gardère's next experiment was performed on a patient in the standing position and focused on methods to detect mild or latent rigidity.[18,19] This test was named "the stiff wrist test " ("test du poignet figé " in French) and was based on the observation that enhanced muscular tone could be easily assessed at the wrist when the patient flexed forward and reached for a glass on a table (Fig. 2). With this maneuver, the investigator could detect rigidity in patients with early PD presenting with a loss of associated movements without any evident rigidity while standing erect. In the midst of the investigator's to-and-fro passive range of motion at the wrist on the patient's more affected parkinsonian side, the wrist would suddenly stiffen as the patient bent forward and stretched his other hand to grasp the glass.[18,19] Froment also tested another activation maneuver for detecting wrist rigidity, based on contralateral active shoulder movements: the patient was asked to "swing his arm around like a windmill " ("moulinet " in French). This latter activation or facilitation test rapidly became known in the French medical literature and was named as "Froment maneuver " (to be distinguished from the expression "Froment sign " reserved for his contribution to the evaluation of ulnar palsy).

The Concept of Maintenance Stabilization and Reactive Stabilization

To further test his theory of an abnormally increased activation of antigravity muscles in PD patients, Froment studied the variation of muscular tone in the wrist among healthy subjects during conditions requiring scaled efforts to maintain balance. He observed that in a healthy individual the muscular tone at the wrist increased in a

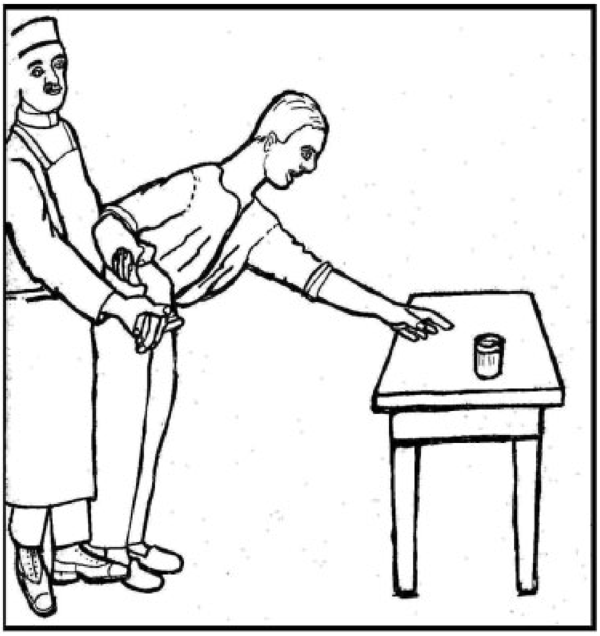

FIG. 2. Drawing from Jules Froment describing "*the stiff wrist test in the bent posture and gesture at the bar* " ("test du poignet figé dans l'attitude et le geste dit du comptoir " in French). This activation or facilitation test was later simplified to having the PD patient "swing his arm like a windmill" ("faire le moulinet du bras " in French) and became known as the "Froment maneuver " (Reproduced from Ref. 19, with permission from Masson Editeur).

scaled fashion depending on conditions of imbalance. For example, bending over to reach for an object, walking on tip toes or standing on one leg induced transient wrist stiffening for a few seconds and then the tone relaxed.[19,20,23] From these observations, Froment and Gardère concluded that there were two types of stabilization mechanisms that protect against postural abberations. First, the *maintenance stabilization* mechanisms (called "stabilization a minima" in French), that hold the pelvis and the trunk in the normal erect position so as to produce muscular contractions that are active in an unstressed condition. Second, the *reactive stabilization* ("stabilization renforcée " in French) that intervenes when the posture is disturbed and muscle activation works to re-establish the ambient posture. The latter requires more effort and a more substantive participation of antigravity muscles. According to Froment and Gardère, the maintenance stabilization mechanisms are fundamentally impaired in PD and the reactive stabilization mechanisms become continually operative, both to maintain posture as well as to respond to postural threats.[18]

In addition, and in keeping with their findings made in normal subjects, Froment and Gardère noticed that in patients with asymmetric parkinsonian signs the stiff wrist was mostly apparent when the patient bent his body towards the more parkinsonian side.[18,23] Froment reasoned that this maneuver stressed the maintenance stabilization mechanisms on the more affected hemibody. Conversely, the stiff wrist was less apparent or even absent when the patient bent towards the more healthy side, suggesting that the less affected hemibody responded more normally to posture-control mechanism.

Physiological Study of the Froment Maneuver

Froment conducted a surface myographic study of rigidity with Vincent-Loison,[20] using a myograph derived from one among others developped by J. Marey, the famous French neurophysiologist of Collège de France in Paris during the second half of the nineteenth century. This apparatus actually used a transducer composed by a membrane similar to that of a drum. The transducer placed on the forearm was connected to a stylus on the kymograph drum. This myograph thus resembles to a vibromyograph (Figs. 3–5). The results of the myographic study of Froment and Vincent-Loison confirmed the clinical observations presented earlier that parkinsonian rigidity is linked to reactive stabilization mechanisms. The study also revealed that situations provoking imbalance, for example, in a normal subject standing on one foot or standing on the heels, induced transient rigidity in the wrist.[20]

Relationship Between Cogwheel Phenomenon and Parkinsonian Rigidity

Froment investigated with Chaix the variations of the cogwheel phenomenon and rigidity[21] in PD patients with different severities of other parkinsonian signs. When the subject was placed in different unstable positions which

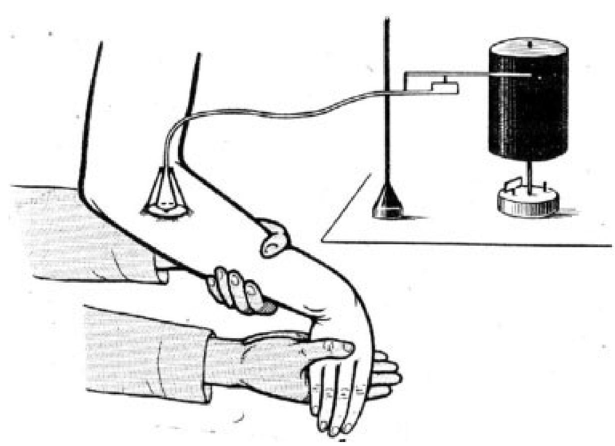

FIG. 3. Experimental apparatus used to record muscle activity with a myograph (see detailed explanations on this technique in the text). This makes possible to record muscle tone changes of the extensor muscles of the forearm during passive movements of the right wrist (Reproduced from Ref. 20, with permission from Masson Editeur).

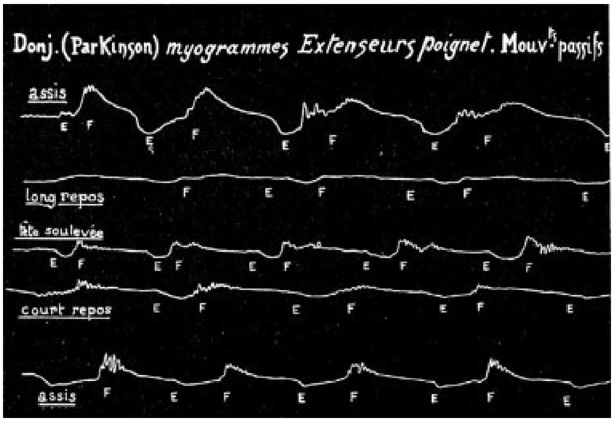

FIG. 4. Myographic recordings of forearm extensors during passive flexion (F)-extension (E) movements of the wrist in a parkinsonian patient in different sitting positions. Line 1 ("assis"): increased muscle tone in antagonist muscles is noted during passive flexion of the wrist while patient is sitting with his head lifted. Line 2 ("long repos"): no muscle tone changes are seen when the patient is seated in a comfortable armchair with the head and four limbs resting for a long time. Line 3 ("tête soulevée"): increased muscle tone reappears if the patient lifts his head. Line 4 ("court repos"): After return to complete but brief rest, a discrete muscle tone is recorded in antagonist muscles during passive flexion of the wrist. Line 5 ("assis"): patient is sitting again in the same condition as in Line 1 (Reproduced from Ref. 20, with permission from Masson Editeur).

were difficult to hold, rigidity and the cogwheel phenomenon could be dissociated: the cogwheel phenomenon stopped and turned to a leadpipe character. For example, in a patient with severe parkinsonism who was lying on a bed, with his legs and arms stretched or half flexed, Froment and Chaix noted that the cogwheel phenomenon was detected at the wrist even if the subject did not move. It was also displayed when the subject was sitting on his bed with his back supported by an aid. When the aid was withdrawn the subject tried not to fall backwards. Simultaneously, the wrist became much more rigid in a leadpipe manner and cogwheel phenomenon completely disappeared. The same pattern was observed when the subject was standing in a situation of imbalance: rigidity was markedly increased, but without the cogwheel phenomenon.[21]

Parkinsonian Rigidity Increases During Romberg Test, Gaze Deviation, and Orientation of Attention

To further elucidate the laws that govern parkinsonian rigidity and its variations in intensity with changing posture, Froment did several experiments published between 1927 and 1929. With Paufique, he showed that the intensity of parkinsonian rigidity increases with the difficulties associated with the Romberg test.[24] These findings were consistent with the previous experiments and confirmed that parkinsonian rigidity is a sign directly correlated with impaired balance. Froment and Paufique continued their research on parkinsonian rigidity by investigating the effects of gaze direction on rigidity.[25] A gaze deviation of as little as 10° appeared sufficient to enhance rigidity. Finally, Froment and Dubouloz revealed that parkinsonian rigidity may vary with the orientation of the patient's attention.[26] Thus, not only gaze orientation but also auditory orientation contribute to static reflexes and thereby can influence rigidity.

FROMENT'S LEGACY TO MODERN NEUROLOGISTS

As emphasized earlier, Froment proposed that rigidity, as a pathological increase in muscular tone, was a response to an impairment in mechanisms involved in the maintenance of normal posture. Rigidity occurred because of the consequential activation of postural control mechanisms normally only utilized when equilibrium was threatened. In his view, this "rigidification " reflected a compensatory neurophysiological response against the laws of gravity. This concept is compatible with the contemporary view that rigidity depends on hyperactive long loop reflexes.[29] In addition to this conceptual framework, Froment left to the neurological community the "Froment's maneuver"[24] and the concept of facilitation. The increase in muscular tone in response to an activation maneuver has indeed become part of the definition of parkinsonian rigidity. From its original description, Froment's maneuver has been defined as "a

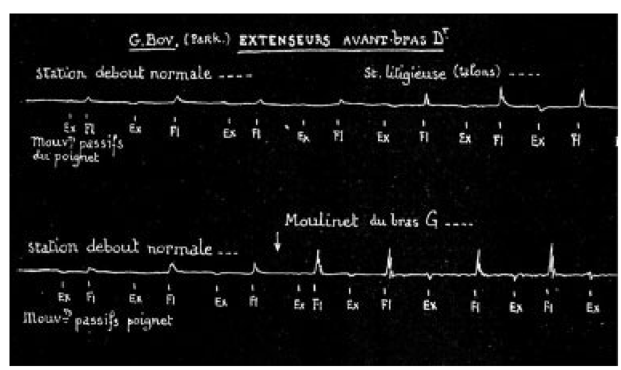

FIG. 5. Myographic recordings of right forearm extensors during passive flexion (F)-extension (E) movements of the right wrist in a parkinsonian patient in different standing positions. Line 1, left half ("station debout normale"): slight increase in muscle tone in antagonist muscles is noted during passive flexion of the wrist while patient is in the normal standing posture. Line 1, right half ("st. litigieuse, (talons)"): muscle tone is enhanced when patient is standing on his heels. Line 2, left half ("station debout normale"): only a slight increase in muscle tone is seen when patient returns to normal standing posture. Line 2, right half ("moulinet du bras G."): a marked increase in muscle tone in antagonist muscles is noted in the right forearm extensors when patient swings his left arm around (Reproduced from Ref. 20, with permission from Masson Editeur).

resistance to passive movements of a limb about a joint that can be detected specifically when there is a voluntary action of another body part".[30]

Even though the name of Froment is not always linked to this maneuver, this test is actually used everyday around the world in clinical practice for the early diagnosis of PD because its sensitivity enables to detect rigidity even when it is latent. The concept of facilitation is formalized in the "gold standard" rating scale for PD, the Unified Parkinson's Disease Rating Scale or UPDRS.[31] In the UPDRS motor scale, the lowest level of rigidity is specifically elicited only by activation of the contralateral body. Further, the renaissance during the last decade of the neurosurgical treatment of PD regularly uses Froment's maneuver to assess the effect on parkinsonian rigidity of deep brain stimulation of the subthalamic nucleus in conscious patients undergoing stereotactic surgery under local anesthesia in the surgical room. Indeed, the assessment of changes in rigidity in response to high frequency electrical stimulation of an electrode in the subthalamic nucleus can help in localizing this target. This task requires a perfect knowledge of all potential variables that can influence muscular tone.[32] This has kindled our interest in Froment's work which is unique in its richness of clinical observations.

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