

Exercise Therapy

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Strength–Duration Curve (SD Curve)

Definition

The strength–duration curve (SD curve), also known as the intensity–duration curve, is a graphical representation of the relationship between the minimum stimulus strength and the stimulus duration required to produce a response in an excitable tissue, such as a nerve or muscle.

The SD curve is used in physiotherapy to assess neuromuscular excitability and help identify normal innervation, partial denervation, and complete denervation.

Uses/ Purpose

1. To assess the electrical excitability of muscles and nerves.
2. To help identify partial or complete denervation.
3. To compare the excitability of affected and unaffected muscles.
4. To assist in evaluating the effects of peripheral nerve injuries.
5. To provide information that may help guide the selection of electrical stimulation parameters.
6. To monitor changes in muscle excitability during recovery from nerve injury.

Principle

- The strength–duration curve is based on the principle that the minimum current required to excite an excitable tissue varies with the duration of the electrical stimulus.
- Short-duration pulses generally require a higher stimulus strength.
- As the stimulus duration increases, the required current strength decreases.
- At longer durations, the curve approaches a minimum current level called the rheobase.
- Denervated muscle fibres generally require longer-duration pulses for direct stimulation than normally innervated muscle, because the motor nerve is no longer available to mediate the usual response.

Rheobase

Rheobase is the minimum current strength required to produce an excitation when the stimulus duration is sufficiently long.

Chronaxie

Chronaxie is the minimum stimulus duration required to produce excitation when the stimulus strength is twice the rheobase.

Kink

A kink is a noticeable change in the direction or slope of the strength–duration curve. It may appear in partial denervation because innervated and denervated muscle fibres have different electrical response characteristics.

Pulse Duration

Pulse duration is the length of time for which an electrical stimulus is applied, usually expressed in milliseconds (ms).

Equipment Required

1. Diagnostic electrical stimulator capable of delivering controlled pulse durations and current amplitudes.
2. Suitable electrodes and connecting leads.
3. Conductive pads or electrode sponges, as appropriate for the equipment.

4. Measuring scale or ruler for electrode placement, if required.
5. Towels and skin-preparation materials.
6. Recording sheet or graph paper for plotting the SD curve.

Technique for Recording the Strength–Duration Curve

A. Preparation

Receiving the patient: Greet the patient, introduce the procedure, and obtain informed consent.

Knowledge of the condition: Review the patient's history, diagnosis, duration of nerve injury, and relevant clinical findings.

Preparation of equipment: Prepare the diagnostic electrical stimulator, electrodes, connecting leads, and recording sheet.

Patient positioning: Position the patient comfortably so that the selected muscle is accessible and relaxed.

Physiotherapist positioning: Stand or sit in a position that allows safe electrode placement, observation of muscle contraction, and adjustment of the apparatus.

Checking contraindications and precautions: Assess skin integrity, sensation, relevant medical conditions, and any device-specific contraindications.

Skin preparation: Clean and dry the skin and reduce skin resistance as appropriate. Avoid irritating or damaging the skin.

Checking the apparatus: Inspect the equipment and leads and confirm that the current intensity and pulse duration can be controlled accurately.

Electrode placement: Place the electrodes over the appropriate motor point or muscle region, following the equipment manufacturer's instructions and standard clinical practice.

B. Procedure/ Method

1. Explain the purpose and procedure to the patient.
2. Explain that the patient may feel a tingling sensation or observe a muscle contraction and should immediately report pain, burning, or unusual discomfort.
3. Instruct the patient to remain relaxed and not to touch the equipment or electrodes during stimulation.
4. Select an appropriate small muscle with a clearly identifiable contraction.
5. Set the diagnostic stimulator to deliver interrupted galvanic current or suitable long-duration pulses, as required by the protocol.
6. Begin with a relatively long pulse duration, such as 100–300 ms, if supported by the equipment and appropriate for the assessment.
7. Increase the current gradually until a minimal, clearly observable muscle contraction is obtained.
8. Record the minimum current strength required to produce the response at that pulse duration.
9. Reduce the pulse duration systematically and repeat the procedure, increasing the current only as necessary to obtain a minimal response.
10. Record the minimum current required at each pulse duration.
11. Continue across the selected range of pulse durations, following the clinical protocol and equipment limits.
12. Plot stimulus duration on the horizontal axis and stimulus strength on the vertical axis.
13. Join the recorded points to obtain the strength–duration curve.
14. Compare the curve with the expected pattern for normal innervation and possible partial or complete denervation.
15. Reduce the current to zero before removing the electrodes, inspect the skin, and document the findings.

C. Instructions to the Patient

1. Remain relaxed throughout the procedure.
2. Report any pain, burning, or unusual discomfort immediately.
3. Do not touch the electrodes, connecting leads, or electrical apparatus during stimulation.
4. Avoid sudden movement while the current is being applied.

Selection of Muscles for Testing

A small muscle with a clearly identifiable action is generally preferred. The affected muscle should be compared with an appropriate unaffected muscle when possible.

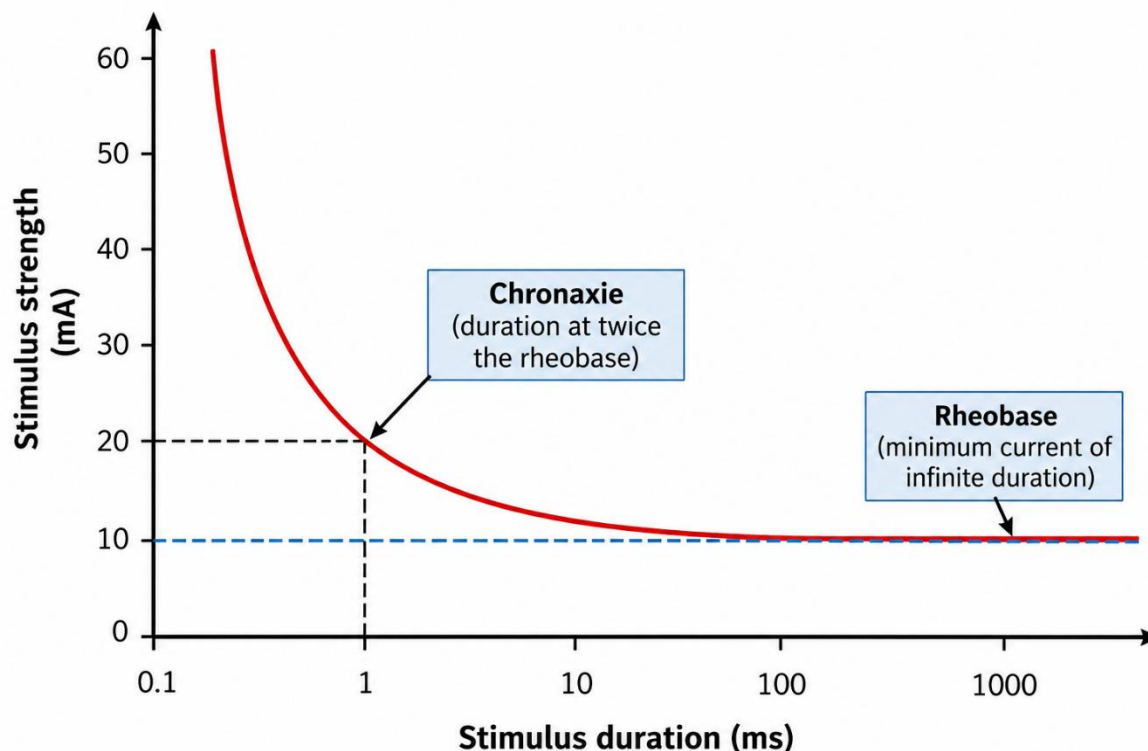
Shape of the Strength–Duration Curve

A. Normal Innervation

When the motor nerve fibres supplying a muscle are intact, the muscle demonstrates the characteristic strength–duration relationship of normally innervated tissue.

Characteristics:

1. Short-duration pulses require relatively high current strength.
2. As pulse duration increases, the current required to produce a response decreases.
3. At longer pulse durations, the curve approaches the rheobase.
4. The curve generally has a smooth, downward-sloping shape.
5. Normally innervated muscle responds readily to short-duration pulses because stimulation activates the motor nerve fibres supplying it.



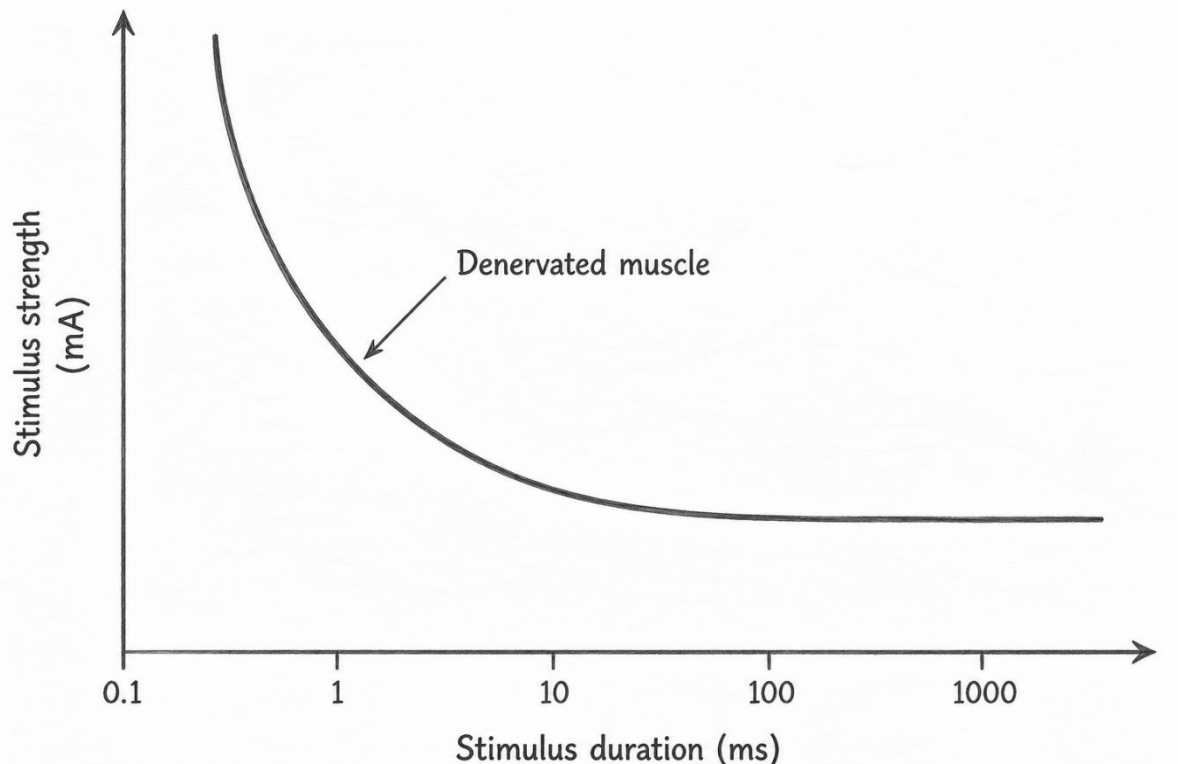
B. Complete Denervation

Complete denervation occurs when the motor nerve supply to the tested muscle is lost.

Characteristics:

1. The muscle fibres must be stimulated directly rather than through intact motor nerve fibres.
2. Relatively long-duration electrical pulses are generally required to produce a contraction.
3. Very short-duration pulses may fail to produce a direct muscle response, even at higher current strengths within the equipment's limits.
4. The curve is shifted towards longer pulse durations compared with the normal pattern.
5. The rheobase and chronaxie may be increased, depending on the degree of denervation and the testing conditions.

Clinical significance: A characteristic denervated pattern supports the possibility of severe or complete denervation but should not be used alone to establish the diagnosis.



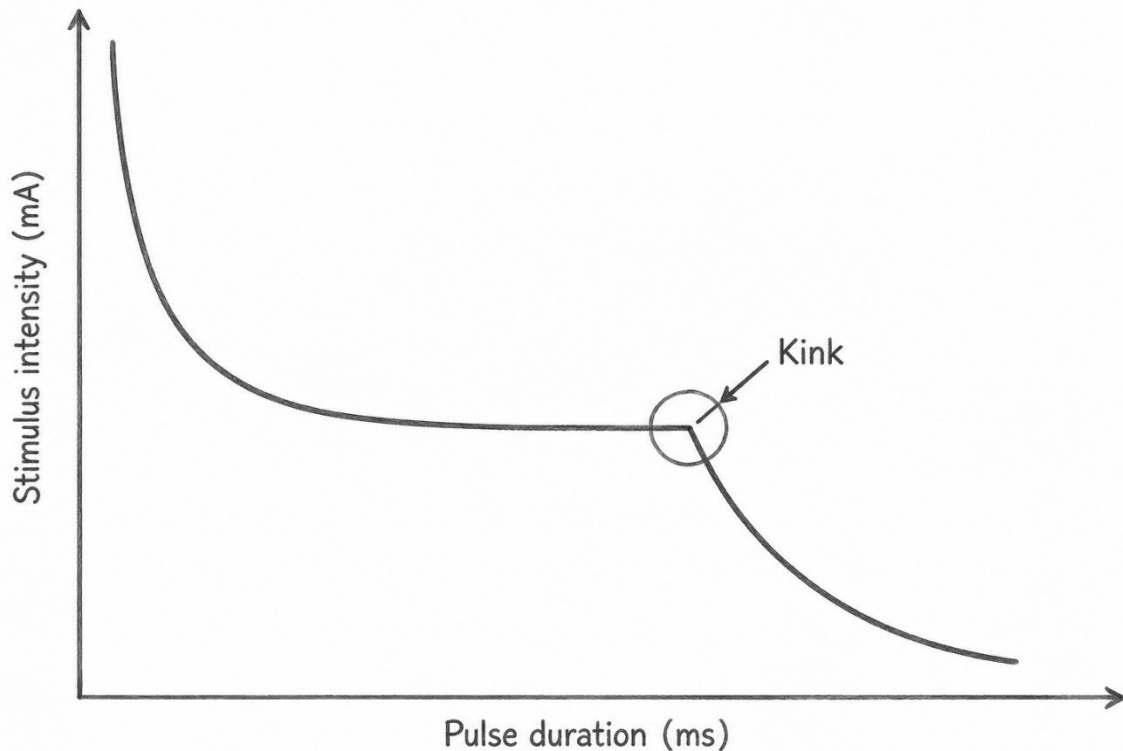
C. Partial Denervation

Partial denervation occurs when some motor nerve fibres supplying a muscle have degenerated while other motor nerve fibres remain intact.

Characteristics:

1. At short pulse durations, the intact motor nerve fibres can produce a muscle response.
2. As pulse duration increases, denervated muscle fibres may also be directly stimulated.
3. The two populations of fibres have different electrical response characteristics.
4. A change in the slope of the curve, known as a kink, may occur where the response characteristics change.
5. The curve may show features of both normally innervated and denervated muscle.

Clinical significance: A kink may suggest partial denervation, but its presence and appearance depend on the extent of nerve damage, muscle condition, electrode placement, and testing technique.



Precautions

1. Use equipment designed for diagnostic electrical stimulation.
2. Check skin integrity and sensation before applying electrodes.
3. Ensure secure electrode contact and appropriate electrode placement.
4. Increase current gradually and avoid unnecessary stimulation.
5. Follow the manufacturer's limits for pulse duration and current intensity.
6. Stop immediately if the patient experiences pain, burning, or an adverse response.
7. Interpret the curve alongside clinical findings rather than in isolation.
8. Do not confuse the response of intact motor nerves with the direct response of denervated muscle fibres.

References

1. Watson, T. (Ed.). *Electrotherapy: Evidence-Based Practice*. Elsevier. Consult the sections on electrical stimulation, electrodiagnosis, and denervated muscle.
2. Robinson, A. J., & Snyder-Mackler, L. *Clinical Electrophysiology: Electrotherapy and Electrophysiologic Testing*. Wolters Kluwer. Consult the sections on electrical stimulation and electrodiagnostic assessment.
3. Cameron, M. H. *Physical Agents in Rehabilitation: An Evidence-Based Approach to Practice*. Elsevier. Consult the sections on electrical stimulation and clinical application.

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