CLAIMS

1. A method of testing a muscle or a muscle group for muscle stiffness or spasticity, the method comprising:

controlling an actuator to periodically change between a pressurized state and a relaxed state such that the actuator in at least the pressurized state provides a cyclic force contributing to at least one deformation of a piezoelectric film, the actuator in at least the relaxed state providing a lateral surface in abutment with the piezoelectric film, the piezoelectric film being variably deformable and conformable to the muscle or the muscle group;

acquiring a signal generated by the at least one deformation of the piezoelectric film, wherein a change in the signal corresponds to the at least one deformation of the piezoelectric film; and

determining a quantitative measure of a muscle spasticity state of the muscle or the muscle group based on the signal.

2. The method as recited in claim 1, wherein the piezoelectric film is conformable to both the actuator in the pressurized state and to the muscle or the muscle group.

3. The method as recited in claim 1, wherein the piezoelectric film is flexible, and wherein the piezoelectric film is variably deformable in response to a stiffness of the muscle or the muscle group.

4. The method as recited in claim 1 or claim 2, wherein the piezoelectric film is held in a test position independently of the cyclic force, the test position being between the lateral surface and the muscle or the muscle group.

5. The method as recited in any one of claims 1 to 4, the method comprising:

controlling a fluid communication between a fluid source and an elastic bag of the actuator, wherein the lateral surface is part of the elastic bag, and wherein the actuator is in the pressurized state if the elastic bag is inflated by the fluid source, wherein the actuator is in the relaxed state if the elastic bag is at least partially deflated.

6. The method as recited in any one of claims 1 to 5, wherein the signal is a time series voltage signal comprising at least one local peak corresponding to the pressurized state.

7. The method as recited in claim 6, wherein a mean amplitude of the at least one local peak corresponds to a degree of severity of a muscle spasticity state.

8. The method as recited in any one of claims 1 to 7, wherein the signal is acquired when the muscle or the muscle group is in one of an isometric contraction and a static state.

9. The method as recited in any one of claims 1 to 7, wherein the signal includes at least one first local peak if the muscle or the muscle group is in a flexion state, and wherein the signal includes at least one second local peak if the muscle or the muscle group is in an extended state.

10. The method as recited in claim 9, the method comprising: determining the muscle spasticity state based on a ratio between the at least one first local peak and the at least one second local peak.

11. The method as recited in claim 9 or claim 10, the method comprising: determining the muscle spasticity state based on a difference between the at least one first local peak and the at least one second local peak.

12. The method as recited in any of claims 1 to 11, the method further comprising: determining a correlation table based on at least one of the following: (i) at least one local peak of the signal, (ii) a mean of plurality of local peak of the signal, (ii) a ratio between at least one first local peak of the signal and at least one second local peak of the signal, (iii) or any combination thereof.

13. The method as recited in claim 1, further comprising: periodically switching the actuator between the pressurized state and the relaxed state; and concurrently acquiring the signal from the piezoelectric film when the muscle is in a transition state, the transition state being characterized by a dynamic motion of the muscle or the muscle group between a flexion state of the muscle and an extended state of the muscle.

14. The method as recited in claim 13, wherein the signal comprises a time series of peaks, the signal including at least one first local peak corresponding to the flexion state, at least one second local peak corresponding to the extended state, and at least one third local peak corresponding to the transition state.

15. The method as recited in claim 14, wherein the at least one third local peak is characterized by a smaller voltage value than each of the at least one first local peak and the at least one second local peak.

16. The method as recited in claim 14 or claim 15, wherein a difference between the at least one third local peak and the at least one first local peak corresponds to a muscle spasticity state.

17. A device for testing a muscle or a muscle group for muscle stiffness or spasticity in accordance with the method as recited in any one of claims 1 to 16, the device comprising:

a piezoelectric film; and

an actuator, the actuator in at least a relaxed state having a lateral surface in abutment with the piezoelectric film, the actuator being operable to periodically change between a pressurized state and the relaxed state such that the actuator in at least the pressurized state provides a cyclic force contributing to at least one deformation of the piezoelectric film, the piezoelectric film being variably deformable and conformable to the muscle or the muscle group, wherein the at least one deformation of the piezoelectric film is configured to generate a signal, and wherein a change in the signal corresponds to the at least one deformation of the piezoelectric film.

18. The device as recited in claim 17, wherein the piezoelectric film is flexible, and wherein the piezoelectric film is variably deformable in response to a stiffness of the muscle or the muscle group, and wherein the piezoelectric film is configured to provide a first signal representative of a first curvature change of the piezoelectric film when the muscle is in flexion and a second signal representative of a second curvature change of the piezoelectric film when the muscle is in extension.

19. The device as recited in claim 17 or claim 18, further comprising a wearable article, wherein the piezoelectric film is held by the wearable article in a test position independently of the cyclic force, the test position being between the lateral surface and the muscle or the muscle group, and wherein the piezoelectric film has a higher tension stiffness along a neutral plane of the piezoelectric film, and wherein the piezoelectric film has a lower bending stiffness about a bending axis in the neutral plane of the piezoelectric film.

20. A system for performing the method of testing a muscle or a muscle group for muscle stiffness or spasticity as recited in any one of claims 1 to 16, the system comprising:

a wearable article;

a piezoelectric film;

an actuator, the actuator including a lateral surface, the actuator being attachable to the wearable article with the piezoelectric film disposed between the lateral surface of the actuator and the muscle or the muscle group, the actuator being configured to enable the piezoelectric film to be variably deformable and conformable to the muscle or the muscle group;

a controller; and

a fluid source, the fluid source being coupled to the controller, the controller being configured to open or close a fluid communication between the fluid source and the actuator to periodically change the actuator between a pressurized state and a relaxed state,

wherein the controller is configured to:

control the actuator to periodically change between the pressurized state and the relaxed state, the actuator in at least the pressurized state providing a cyclic force contributing to at least one deformation of the piezoelectric film, the actuator in at least the relaxed state having the lateral surface in abutment with the piezoelectric film;

acquire a signal generated by the at least one deformation of the piezoelectric film, a change in the signal corresponding to the at least one deformation of the piezoelectric film; and

determine a quantitative measure of a muscle spasticity state of the muscle or the muscle group based on the signal.