**5STS – THE FIVE TIMES SIT-TO-STAND**

The five times sit-to-stand is a protocol for assessing the transfer skills when standing up and sitting down on a chair. The related performance indicators are linked to a general level of lower extremity strength, transitional movements, balance and fall risk, and have been shown to be correlated to the general mobility of a subject in everyday life.

**Technical description of the protocol:**

**Initial position and recommendations:**

The protocol is completely administered on the BENCH testbed. It is generally recommended that the protocol starts with the subject leaning on the backrest of the chair, but depending on the subject height and on the testbed configuration (i.e. seat height), this recommended initial position is not mandatory and can be simply replaced with a sat comfortable position of the subject. The buttocks must in contact with the seat, the feet must be in contact with the ground and the arms must be folded across chest (with crossed wrists). It is recommended that the feet are kept symmetrical on the ground, and that the position of the feet does not change along the execution of the test. From literature, the recommended height of the seat is 43-45 cm from the ground, but the height of the seat is a controllable parameter for the execution of the test.

**Test Execution:**

The subject is instructed to stand up and sit down 5 times as quickly as he can. The test starts when a GO signal is received. The test ends when the buttocks touch the sit for the fifth time, right after the fifth stand-to-sit movement. The subject must be instructed to stand fully after each sit-to-stand cycle. Moreover, the subject must be instructed to not touch the backrest between consecutive cycles (the only contact with the backrest should be the initial one). After the GO signal, the subject must execute the test without any external interference (e.g. incitation or pressure to go faster), since they could affect the PIs. The test can be administered as many times as the experimenter needs.

**Performance Indicators:**

The following 7 PIs are calculated from the 5STS protocol.

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PI1: 5STS duration - it is calculated as the time elapsed between the first movement after the GO signal and the fifth dynamic contact with the chair (thus excluding the initial static contact). Data from both the Chair and lower limb kinematics are needed for calculating this PI.

Corresponding function: *sts\_duration\_5sts.m*

Recalled functions: *none*

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PI2: STS subphases duration - this PI consists of a 3 elements array of scalars indicating the average duration of each STS subphase. Each subphase duration is the average across the 5 sit-to-stand cycles characterizing the protocol. The 3 phases are defined according to Caruthers et al. 2016, and based on the 4 time points:

* 1: t0: in each STS cycle, the start corresponds to the first trunk bending after the 0 velocity has been reached
* 2: lift-off: when the COP vertical force of the seat force plate goes to 0
* 3: maximum ankle dorsiflexion: corresponds to the point at which the shank bends over the foot, generating a maximum ankle dorsiflexion.
* 4: full hip extension: detected when the hip is fully extended, the sit-to-stand cycle ends. A subsequent beginning of the hip flexion identifies the beginning of the stand-to-sit cycle

These 4 points in each cycle lead to the following 3 subphases:

* Phase 1: Forward leaning
* Phase 2: Momentum transfer
* Phase 3: Extension

Data from both the Chair and lower limb kinematics are needed for calculating this PI.

Corresponding function: *segment\_sts.m*

Recalled functions: *none*

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PI3: STS CoP stability – this PI consists of a 2 elements array of scalars indicating the average distance travelled by the CoP both in AP and ML directions. Distance data are averaged across the 5 STS cycles. Data from both the Chair and lower limb kinematics are needed for calculating this PI.

Corresponding function: *sts\_CoP\_stability.m*

Recalled functions: *none*

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PI3\_alternative - STS CoP stability – this PI consists of a 2 elements array of scalars indicating the dynamic margin of stability during the execution of STS. MoS is calculated as the distance between the extrapolated center of mass xCoM and the center of pressure CoP both in the AP and ML directions.

Corresponding function: *sts\_CoP\_stability2.m*

Recalled functions: *sts\_CoM.m*

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PI4: Time needed for unidirectional load transfer – this PI is an two elements array of scalars indicating the AP and ML unidirectional load transfer overshoot times, corresponding to the time at which the distance between the quiet standing CoP position and the local maxima of anteroposterior and medio-lateral CoP during sts transition are reached. The data is averaged across 5 STS cycles. Data from both the Chair and lower limb kinematics are needed for calculating this PI.

Corresponding function: *unidirectional\_load\_transfer.m*

Recalled functions: *none*

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PI5: Unidirectional load transfer overshoot – this PI is an two elements array of scalars indicating the AP and ML unidirectional load transfer overshoot as the distance between the quiet standing CoP position and the local maxima of anteroposterior and medio-lateral CoP during sts transition. The data is averaged across 5 STS cycles. Data from both the Chair and lower limb kinematics are needed for calculating this PI.

Corresponding function: *unidirectional\_load\_transfer.m*

Recalled functions: *none*

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PI6: kinematic repeatability – this PI is a four elements array of scalars indicating the regularity of the ankle, knee, hip and trunk kinematics, respectively. Regularity is calculated through the normalized autocorrelation of the kinematics. In particular, for knee and hip the regularity corresponds to amplitude of the first peak of the normalized auto-correlation function at lag different from zero, while for the ankle and trunk it corresponds to the second peak. Only kinematic data are needed for calculating this PI

Corresponding function: *kinematics\_repeatability.m*

Recalled functions: *none*

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PI7: total mechanical power – this PI consists of a scalar indicating the total mechanical work done by the Center of mass. The CoM work is calculated as the scalar product between the CoM velocity and the force plates resultant force

Corresponding function: *tot\_mech\_pwr.m*

Recalled functions: *sts\_CoM.m*

**30sSTS – THE 30 SECONDS SIT-TO-STAND**

The 30 seconds sit-to-stand is a protocol for assessing the transfer skills when standing up and sitting down on a chair. The related performance indicators are linked to a general level of lower extremity strength, transitional movements, balance and fall risk, and have been shown to be correlated to the general mobility of a subject in everyday life.

**Technical description of the protocol:**

**Initial position and recommendations:**

The protocol is completely administered on the BENCH testbed. It is generally recommended that the protocol starts with the subject leaning on the backrest of the chair, but depending on the subject height and on the testbed configuration (i.e. seat height), this recommended initial position is not mandatory and can be simply replaced with a sat comfortable position of the subject. The buttocks must in contact with the seat, the feet must be in contact with the ground and the arms must be folded across chest (with crossed wrists). It is recommended that the feet are kept symmetrical on the ground, and that the position of the feet does not change along the execution of the test. From literature, the recommended height of the seat is 43-45 cm from the ground, but the height of the seat is a controllable parameter for the execution of the test.

**Test Execution:**

The subject is instructed to stand up and sit down as quickly as he can. The test starts when a GO signal is received. The test ends exactly after 30 seconds from the start. The subject must be instructed to stand fully after each sit-to-stand cycle. Moreover, the subject must be instructed to not touch the backrest between consecutive cycles (the only contact with the backrest should be the initial one). After the GO signal, the subject must execute the test without any external interference (e.g. incitation or pressure to go faster), since they could affect the PIs. The test can be administered as many times as the experimenter needs.

**Performance Indicators:**

The following 7 PIs are calculated from the 30sSTS protocol.

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PI1: 30sSTS repetitions - it is calculated as the number of full sit-to-stand cycles executed in the 30s after the GO signal. Only the data coming from the kinematics are used for calculating this PI.

Corresponding function: *repetitions\_30sSTS.m*

Recalled functions: *none*

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PI2: STS subphases duration - this PI consists of a 3 elements array of scalars indicating the average duration of each STS subphase. Each subphase duration is the average across the N sit-to-stand cycles characterizing the protocol. The 3 phases are defined according to Caruthers et al. 2016, and based on the 4 time points:

* 1: t0: in each STS cycle, the start corresponds to the first trunk bending after the 0 velocity has been reached
* 2: lift-off: when the COP vertical force of the seat force plate goes to 0
* 3: maximum ankle dorsiflexion: corresponds to the point at which the shank bends over the foot, generating a maximum ankle dorsiflexion.
* 4: full hip extension: detected when the hip is fully extended, the sit-to-stand cycle ends. A subsequent beginning of the hip flexion identifies the beginning of the stand-to-sit cycle

These 4 points in each cycle lead to the following 3 subphases:

* Phase 1: Forward leaning
* Phase 2: Momentum transfer
* Phase 3: Extension

Data from both the Chair and lower limb kinematics are needed for calculating this PI.

Corresponding function: *segment\_sts.m*

Recalled functions: *none*

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PI3: STS CoP stability – this PI consists of a 2 elements array of scalars indicating the average distance travelled by the CoP both in AP and ML directions. Distance data are averaged across the N STS cycles coming from PI1. Data from lower limb kinematics are needed for calculating this PI.

Corresponding function: *sts\_CoP\_stability.m*

Recalled functions: *none*

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PI3\_alternative - STS CoP stability – this PI consists of a 2 elements array of scalars indicating the dynamic margin of stability during the execution of STS. MoS is calculated as the distance between the extrapolated center of mass xCoM and the center of pressure CoP both in the AP and ML directions.

Corresponding function: *sts\_CoP\_stability2.m*

Recalled functions: *sts\_CoM.m*

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PI4: Time needed for unidirectional load transfer – this PI is an two elements array of scalars indicating the AP and ML unidirectional load transfer overshoot times, corresponding to the time at which the distance between the quiet standing CoP position and the local maxima of anteroposterior and medio-lateral CoP during sts transition are reached. The data is averaged across 5 STS cycles. Data from both the Chair and lower limb kinematics are needed for calculating this PI.

Corresponding function: *unidirectional\_load\_transfer.m*

Recalled functions: *none*

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PI5: Unidirectional load transfer overshoot – this PI is an two elements array of scalars indicating the AP and ML unidirectional load transfer overshoot as the distance between the quiet standing CoP position and the local maxima of anteroposterior and medio-lateral CoP during sts transition. The data is averaged across 5 STS cycles. Data from both the Chair and lower limb kinematics are needed for calculating this PI.

Corresponding function: *unidirectional\_load\_transfer.m*

Recalled functions: *none*

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PI6: kinematic repeatability – this PI is a four elements array of scalars indicating the regularity of the ankle, knee, hip and trunk kinematics, respectively. Regularity is calculated through the normalized autocorrelation of the kinematics. In particular, for knee and hip he regularity corresponds to amplitude of the first peak of the normalized auto-correlation function at lag different from zero, while for the ankle and trunk it corresponds to the second peak. Only kinematic data are needed for calculating this PI

Corresponding function: *kinematics\_repeatability.m*

Recalled functions: *none*

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PI7: total mechanical power – this PI consists of a scalar indicating the total mechanical work done by the Center of mass. The CoM work is calculated as the scalar product between the CoM velocity and the force plates resultant force

Corresponding function: *tot\_mech\_pwr.m*

Recalled functions: *sts\_CoM.m*