The impact of flexion or extension movement transfer pattern on a performance of sit-to-stand task in asymptomatic young subjects

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A shortened title: The performance of sit-to-stand task

Aims. To assess a mode of sit-to-stand (STS) task performed in a habitual manner or with flexion or extension pattern transfer in asymptomatic young subjects. It was hypothesized that different initial movement of the lumbar-pelvic region would modify a performance of STS task: coordination of STS in time and level of vertical ground reaction forces (GRF).

Methods. A convenience sample of 30 young asymptomatic volunteers, both genders, was recruited. The STS task was performed in a habitually manner (STS_hab) or performed with flexion (STS_flex) or extension (STS_ext) pattern. Kistler platform was used for measure vertical GRF and time of STS phases.

Results. ANOVAs analysis revealed the main effect in total time and in maximum vertical GRF during STS maneuver in three STS tasks ($F(2, 58) = 21.67\text{-}30.74$; $p < 0.00001$). In post-hoc analysis: there wasn't difference in total time between flexion and extension pattern of STS ($p > 0.05$), there wasn't difference between flexion and extension pattern in minimum vertical GRF ($p > 0.05$), but the latter task was the longest in preparation time ($p < 0.001$). There was the lowest maximum vertical GRF in extension pattern of STS ($p < 0.01$).

Conclusions. The extension or flexion movement pattern modified STS performance and displayed different coordination in time and level of vertical GRF. Young asymptomatic participants performed the STS task longer with flexion or extension pattern than in the habitual pattern. The extension pattern of STS had a capacity to produce the lowest vertical GRF.

Key words: ground reaction force, coordination, transfer, STS, mobility

Introduction

Transfer of the body from sitting to standing is important for functional independence in everyday activity. The STS (sit-to-stand) movement is performed on average 60 (± 22) times a day in a working population, but employment type and location and a working day had a significant effect on the number of STS movements performed in a day (1). Test transition from a sitting position to a standing position in recent years has become very popular, especially in clinical trials (2, 3), as it is a basic test for transfer function in neurologically impaired patients.

From clinical point of view, the STS requires the ability to coordinate motion in the desired direction, movement of the lower limbs, correcting muscle strength and balance control and stability, and the ability to adapt to changing task and environmental conditions (4). Subjects with balance disorders performed the Five-Times-Sit-to-Stand Test more slowly than subjects without (5). The longer duration of STS in patients represents a compensatory pattern to address muscle weakness of the lower limb in hemiplegic patients (3).

Characteristic movements of STS are marked by four phases. Preparation – flexion, momentum-transfer, extension and stabilization. The last phase starts when a hip extension is reached and ends when all motion associated with postural stability is completed (6, 7).

Between healthy persons, the duration of STS phases is comparable, as the time course and magnitude of forces is exerted on the ground. During this common STS maneuver, a momentum-transfer strategy is used, based on a trade-off between stability and force requirements and coordination and strength between lower and upper part of the body (4, 7). This strategy does not need high lower extremity forces because the body is already in motion as it begins to lift. On the other hand, people with motor deficits may show distinct departures from the latter STS pattern that result from the need to use compensatory strategies to overcome the neural and/or muscular deterioration. For example, the zero-momentum strategy ensures greater stability but requires flexing the trunk sufficiently to bring the center of mass (COM) well within the base of support of the feet prior to lift-off. This, however, requires the generation of larger lower-extremity forces in order to lift the body to vertical (4).

In 3-D kinematic data of multi-segmental torso, flexion and extension patterns of STS were discovered (8). For the pattern with a high hip joint contribution, the least flexion occurred at the head and the magnitude of flexion increased through each adjacent segment, with the pelvis showing the greatest flexion. This extension strategy of segment motion was consistent with the torso joint extension displayed by many of the participants. This strategy involved the hip performing most of the flexion, with the pelvis remaining highly associated with the other torso segments. For the pattern with higher lumbar/pelvis contribution, the pelvis flexed less and later than the lumbar and mid-thoracic segments, remaining in flexion while all other joints were extending. This flexion strategy indicates that the higher torso segments were flexing forward and extending somewhat independent of pelvis motion (8).

A component of STS considered as critical is 'flexion of the extended trunk at the hips' to move the body mass forward in the preparation phase, with 'flexion of the spine instead of at the hips' being considered a common motor problem (9).

To the best of our knowledge there isn't an analysis of time and events of vertical ground reaction force (GRF) in flexion or extension movement transfer pattern. We would like to add understanding what was the role of the lumbar-pelvic movement in the performance of STS task, based on the findings that this area plays a crucial kinematic role during the sit-to-stand movement in healthy subjects (8). The aim of the study was to assess a mode of STS task performed in a habitual manner or performed in flexion or extension pattern transfer in asymptomatic young subjects. It was hypothesized that different initial movement of the lumbar-pelvic would modify the performance of STS task and displayed different coordination in timing and level of vertical GRF. We would like to explain whether differentiate in performing the STS task observed within a young population without current musculoskeletal issues indicate on different characteristic events of vertical reaction force and time of phases.

Subjects

A convenience sample of 30 volunteers, both genders (18 women and 12 men) who were not involved in any regular physical activity, was recruited from the authors' institution. The inclusion criteria encompassed asymptomatic subjects (NRS=0; Numerical Rating Scale of pain) aged 22-23 years with no history of CLBP (Chronic Low Back Pain) and normal weight (18.5–24.9 kg/m2). Body mass index (BMI) was calculated and classified according to standard WHO criteria (10). The average mass of bodies in the surveyed students was 66.3 ± 13,4kg, while the average body height was 1.75 ± 0,11m. The exclusion criteria were as follows: neurological disease; orthopedic problems of the spine, hip, knee or foot; low back pain at the time of testing; any indication of poor physical or mental state on the day of examination.

All participants provided their informed consent prior to enrollment in the study and the study procedures received the approval of the Ethics Committee of the local university.

Experimental protocol

STS assessment began with the participant assuming a comfortable erect stance on one force plate (Kistler, Type 9286) in front of a standard chair with the feet hip-width apart and the arms along the trunk in a habitual manner. The participant was instructed to assume a comfortable unsupported sitting position and then, immediately after a visual signal, to start the STS maneuver. The STS task was repeated three times, with a break time as a washout period. The movement STS task was performed in a habitually (STS_hab) manner or performed with the lumbar spine in flexion (STS_flex) or extension (STS_ext) in a preparation phase. The order of the experimental condition was randomly assigned to avoid any order effect.

Force platform measures were taken for three dimensions, for each participant. The resulting plot displayed four distinct events in the time course of vertical ground reaction forces (VGRF). These events, in order of occurrence, following the initiation signal, were: initial force at seat unloading, counter force (Fmin) at the beginning of the upward acceleration, vertical peak force (Fmax) achieved after seat off, and post-peak rebound force (Fstab) which transitions into the final stabilization phase (2). In order to eliminate the effect of body weight on ground reaction forces, the results were normalized [(F/body weight) x 100%]. Phases times were analyzed using actual times (real times of raw force recordings) of the consecutive force events following the initiation signal: total time of STS – time from initial force to gain standing stable position (Ttot), preparation phase – time from initial force to counter force (Tmin), extension phase – time from counter force to vertical peak force (Tmax), stabilization phase – time from vertical peak force to post-peak rebound force (Tstab), (Fig.1). All measures of force and phases times were used to compare the STS tasks.

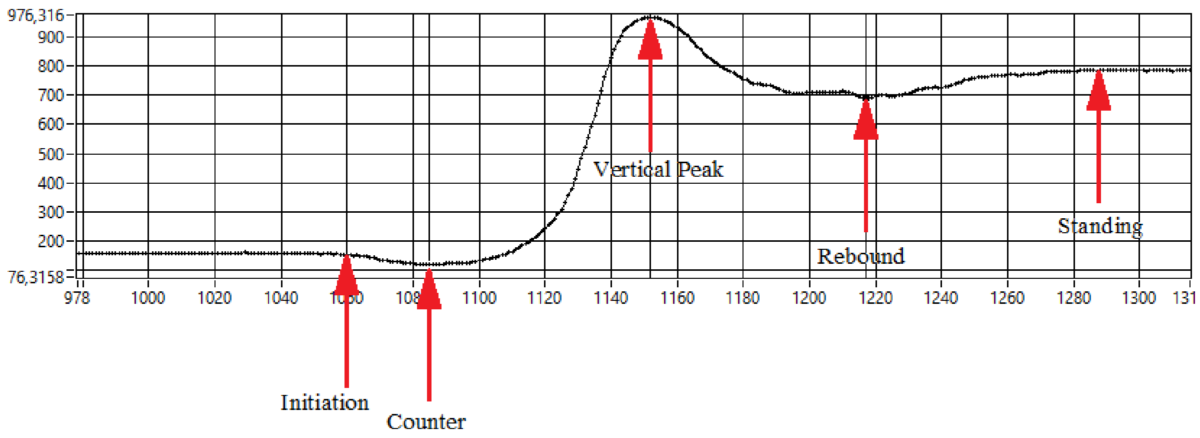

Figure 1. Exemplary raw force recordings

Statistical analysis

Power analysis and sample size selection were performed prior to the study. Assuming a clinically significant effect size of 10% peak force, a sample size of 30 participants was sufficient to provide a study design with acceptable power (0.8) at $p<0.05$. The data obtained from the three trials were averaged and then subjected to statistical analysis in Statistica 12.5 (StatSoft).

Intraclass correlation coefficients ($ICC_{2,1}$) indicated that the measurements of vertical GRF and events times in STS had high and good reproducibility (11). The Shapiro–Wilk test indicated that results the forces and the event times were normally distributed. ANOVA (3 TASK × 3 EVENT) was used for main effects followed by Tukey's post-hoc test.

The mean value and 95% confidence interval were used in figures. The two-sided alpha level was set at $p < 0.05$.

Results

Total time from sit to stand position

ANOVAs analysis revealed the main effect in total time STS maneuver in three movements STS tasks ($F(2, 58) = 30{,}74$, $p < 0.00001$). The shortest total time of STS was performed in a habitual manner. The post-hoc tests indicate significant differences between total time of STS_hab pattern and both STS_flex and STS_ext pattern ($p < 0.05$). There wasn't difference in total time between latter strategies ($p > 0.05$) (Figure 2).

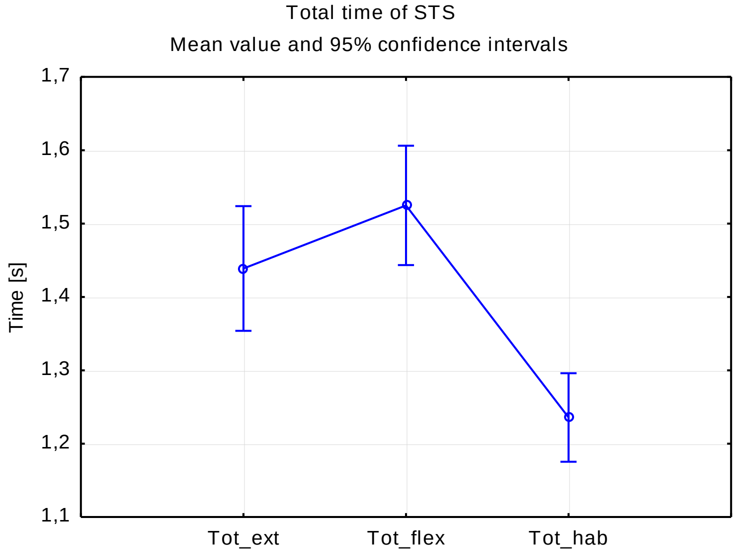

Figure 2. Total time of STS performed habitually (Tot_hab), with flexion (Tot_flex) or extension pattern (Tot_ext)

Preparation phase

ANOVAs analysis revealed the main effect in time to a minimum of VGRF during three movements STS tasks (F(2, 58) = 11,102, p = 0.00008). The shortest Tmin of STS were performed habitually and performed in flexion pattern. There weren't significant differences of time to min between STS_hab and STS_flex pattern (p>0.05). Truly, post-hoc differences revealed between time to min VGRF in STS_ext pattern and STS_flex and STS_hab pattern (p < 0.001) (Figure 3).

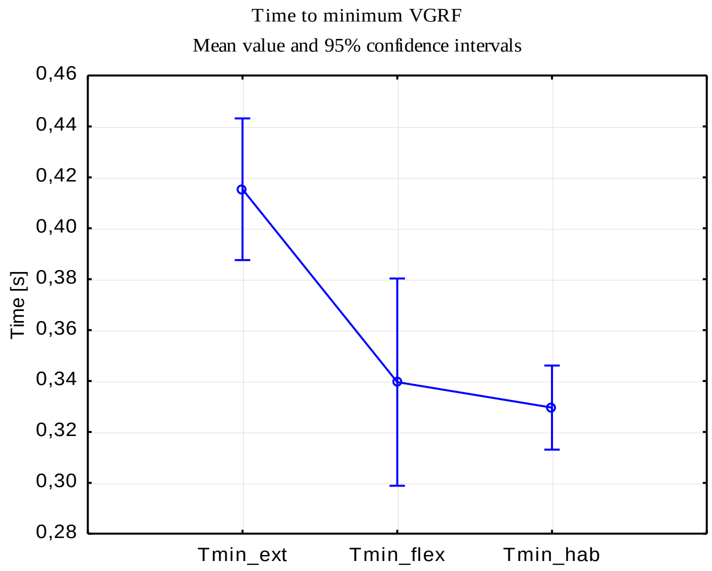

Figure 3. Time to minimum VGRF in STS performed habitually (Tmin_hab), with flexion (Tmin_flex) or extension pattern (Tmin_ext)

Extension phase

ANOVAs analysis revealed the main effect in a time to a maximum of VGRF during STS maneuver in three movements STS tasks (F(2, 58) = 47.117, p = 0.00000). The shortest time to maximum VGRF of STS was identified in STS performed habitually and the longest was performed with flexion of the lumbar spine. There were significant differences between time to max VGRF in STS_flex and STS_hab and STS_ext (p < 0.001). There wasn't difference between the time to max VGRF in STS_hab and STS_ext (Figure 4).

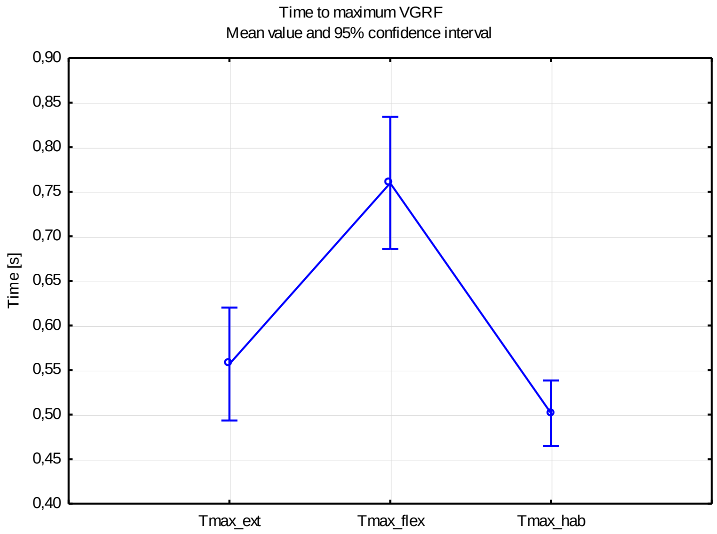

Figure 4. Time to maximum VGRF in STS performed habitually (Tmax_hab), with flexion (Tmax_flex) or extension pattern (Tmax_ext)

Stabilization phase

ANOVAs analysis revealed the main effect in time to post-peak rebound of VGRF in three movements STS tasks (F(2, 58) = 3.7523, p = 0.02935). The shortest time to post-peak rebound force was identified in STS performed habitually and the longest time was in STS performed with an extension of the lumbar spine. There was the only significant difference, between them (p < 0.05).

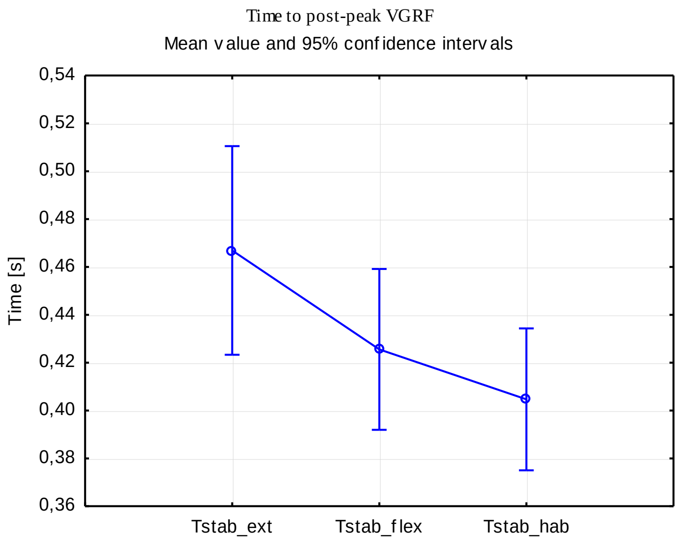

Figure 5. Time to post-peak VGRF in STS performed habitually (Tstab_hab), with flexion (Tmax_flex) or extension pattern (Tmax_ext)

Normalized minimum VGRF

ANOVAs analysis revealed the main effect in Fmin VGRF of STS maneuver in three movements strategies (F(2, 58) = 14,878, p = 0.00001). There were significant differences between minimum VGRF in STS_hab and STS_flex and STS_ext ($p < 0.0001$). There wasn't difference in min VGRF between both latter tasks ($p > 0.05$).

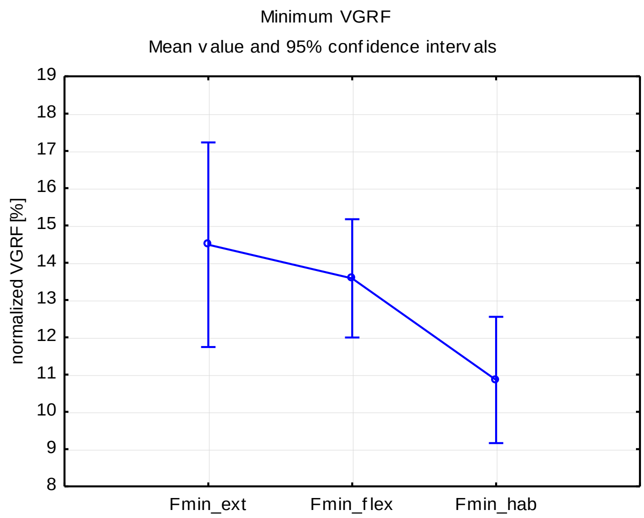

Figure 6. Normalized minimum VGRF in STS performed habitually (Fmin_hab), with flexion (Fmin_flex) or extension pattern (Fmin_ext)

Normalized maximum VGRF

ANOVAs analysis revealed the main effect in maximum VGRF in STS maneuver in three movements tasks (F(2, 58) = 21,670, p = 0.00000). The most dynamic performance of STS was identified in the STS_hab pattern and the least in STS_ext pattern. There were significant differences between maximum VGRF in STS_hab pattern and STS_ext ($p < 0.0001$) and STS_flex ($p < 0.01$) and between both latter tasks ($p < 0.01$) (Figure 7).

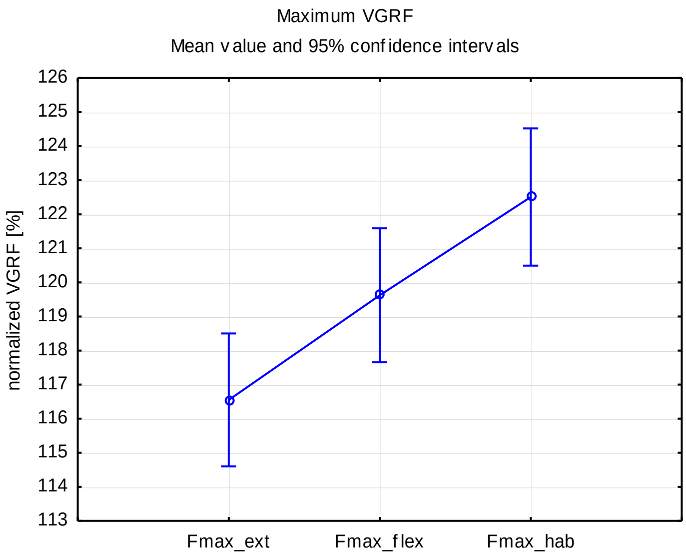

Figure 7. Normalized maximum VGRF in STS performed habitually (Fmax_hab), with flexion (Fmax_flex) or extension pattern (Fmax_ext)

Normalized minimum post-peak VGRF

ANOVAs analysis revealed the main effect in the post-peak VGRF in STS maneuver in three movements tasks ($F(2, 58) = 7{,}7220$, $p = 0.00106$). Stabilization phase in the STS_hab pattern was the least dynamic. There was the only significant difference between the vertical force in STS_hab pattern and STS_flex pattern ($p < 0.0001$) (Figure 8).

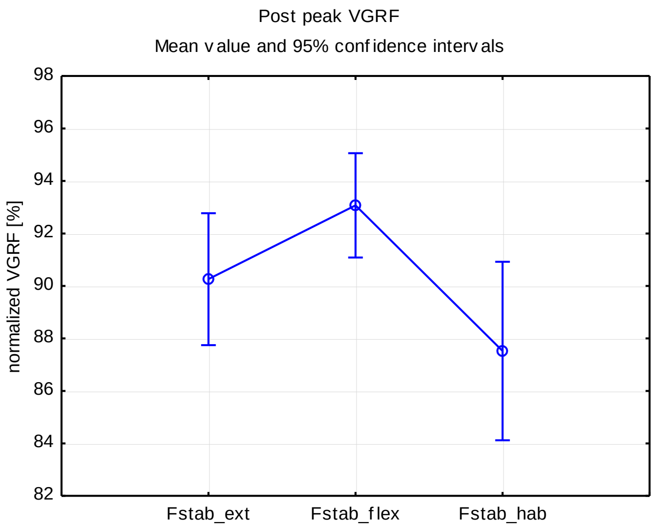

Figure 8. Normalized post-peak VGRF in STS performed habitually (Fstab_hab), with flexion (Fstab_flex) or extension pattern (Fstab_ext)

Discussion

It was hypothesized that different initial movement of the lumbar-pelvic would modify the performance of STS task and displayed different coordination in timing and level of vertical GRF. The results of the study indicate on different characteristic events of vertical reaction force and time of phases which depends on performing the STS task in the young population. Three findings were the most interesting. First, there wasn't difference in total time between flexion and extension the mode of STS. Second, there wasn't difference between flexion and extension STS task in minimum vertical GRF during the preparation phase, but the extension STS task was the longest in preparation time. Third, the most interesting, only this latter pattern characterized similar extension phase as the habitual pattern with the least maximum vertical GRF.

STS duration varied significantly, from 1.23 s for habitual to 1.43 s for extension and 1.53 s for flexion trials, these values were consistent with results found in the literature (12, 13). In Mazza et. al. study (12) average duration of STS task performed with natural speed was identified at 1.6 s (*SD* = 03) with no significant differences associated with the different foot positions. However in own study the total time of STS was impacted by the pattern of STS, new patterns make the STS duration longer. It is interesting that the longest preparation phase characterized the extension STS pattern with no differences in the VGRF. This finding has supported the study of Hamaoui and Alamini-Rodrigues (14), experimentally increased muscular tension along the trunk requires an adaptation of the early postural activity, termed anticipatory postural adjustments, which become longer, to maintain the same level of performance in the STS (14).

The shortest total time of STS and time of each phase were identified only during the habitual STS task. Proper coordination in habitual pattern causes the most dynamic movement. The center of gravity shifts forward and the angular velocity is increased to facilitate the change from a sitting position to a standing patient without pain (5). When the natural process of STS in the preparation phase, the moments of separation of buttocks is a simultaneous flexion of the trunk and increasing the pelvic anteversion (15). Longer time needed to properly complete the task in the erect position and a bent, it is dependent on the position of the center of gravity of the body, which is outside of your feet, unnatural alignment of the spine in the lumbar region, and imposed new model transition to standing.

Imposed a new motor strategy to change body position from sitting to standing clearly extended time tasks in each stage of the STS. It was assumed that flexion and extension patterns were affected by learning. Construction of a new motor activity requires a lot of processing information. They are regularly developed and tailored specific solutions unusual pattern. The fastest movements are executed without the possibility of adjustment to, or flexibility.

In people with normal weight at the natural embodiment of the transition from sitting to standing, in which the trunk is bent and leaning forward was the opposite situation. Greater torque in the hip and lower knee affects the value of the ground reaction force (16).

In the extension phase, the greatest value of the vertical GRF received the subjects tested during the habitual pattern. From the smallest force interacted platform stabilographic subjects during the extension pattern of STS. In this phase, the characteristic of CLBP patients, in which there is a mechanism to avoid the noted lower surface reaction force in the extension phase and a prolonged time to peak force (11). It assumed that extension pattern of STS could be used in decreasing of vertical GRF in general pain population patients.

The neutral position of a spine in the activity of daily living is recommended for low back patients, to decrease a load or eliminate pain in motion (17). A modification to the sit-to-stand technique may provide instantaneous relief of pain and may represent the most cost-effective strategy to reduce overall back pain (18). In this context, the proper performing STS could be an element of prophylaxis of back pain problem. Moreover, different disturbances in movements were observed in CLBP patients: delayed of anterior pelvic movement in STS (2), lack of synergy between movements of hip and lumbar spine (19), changes in the kinematics and coordination of the lumbar spine and hips during sit-to-stand and stand-to-sit (20). The flexion pattern of STS with lumbar spine flexed more and the pelvis flexed less could be a reason of repetitive overload in soft tissues in the lumbar spine in working population. However, data by Tully et al. (15) indicate that both the hips and lumbar spine flex concurrently to bring the body mass forward prior to lifting off, with the lumbar spine contributing 1^0 for every 3.1^0 hip flexion.

During the stabilization, in the last phase of the STS, the subjects showed the least impact on the ground in the habitual pattern of STS. The biggest vertical GRF were during the flexion pattern of STS. This may result from the largest displacement of the center of gravity of the body. Not without significance is also the imposition of a new pattern perform well-known operations. The habitual position of the spine when standing up is a natural position, that it was repeated many times. This affects the liquidity of the task. This ability is acquired through training. Science and improvement of new motor patterns are supported by the plasticity of the nervous system (21). Only to repeat the new task causes the formation of new connections between neurons and a transaction is to consolidate (22). The liquidity of a move is bound to the muscle tone of individual body segments, contributing to the strength of ground reaction test phases STS.

Limitations

This study had a number of limitations. The results of this study could not conclude on muscle activity or pelvis–lumbar spine kinematics, they were not controlled during sit-to-stand tasks. The range of pelvis–lumbar spine motion is one of the factors involved in the sit-to-stand movement, and its contribution should be clarified in future studies. The study was done only with young, asymptomatic subjects both genders and results couldn't be addressed to CLBP patients or elderly subjects.

Conclusion

The extension or flexion movement transfer pattern modified performance of STS and displayed different coordination in time and level of vertical GRF. Young asymptomatic participants performed flexion or extension pattern STS longer than in habitual pattern. The extension pattern of STS had a capacity to produce the lowest vertical GRF. There is a need to study contribution lumbopelvic motion in flexion and extension pattern of STS in healthy working population.

Conflict of interest statement

Authors state no conflict of interest.

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