ORIGINAL PAPER

Physiotherapy Quarterly (formerly Fizjoterapia)
2017, 25 (1), 17–22

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

doi: 10.1515/physio-2016-0012

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Abstract

Introduction. To assess the 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 movements of the lumbar-pelvic region would modify the performance of the STS task: coordination of STS in time and level of vertical ground reaction forces (VGRF).
Methods. A convenience sample of 30 young asymptomatic volunteers, both genders, was recruited. The STS task was performed in a habitual manner or with a flexion or extension pattern. A Kistler platform was used to measure the VGRF and time of STS phases.
Results. ANOVAs analysis revealed the main effect in the total time and in maximum VGRF during the STS manoeuvre in three STS tasks ($F(2, 58) = 21.67–30.74$; $p < 0.00001$). In the post-hoc analysis, there was no difference in the total time between flexion and extension pattern of STS ($p > 0.05$), there was no difference between the flexion and extension pattern in minimum VGRF ($p > 0.05$), but the latter task was the longest in preparation time ($p < 0.001$). The lowest maximum VGRF was bound with the 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 VGRF. Young asymptomatic participants performed the STS task longer with flexion or extension pattern than in the habitual pattern. The extension pattern of STS had the capacity to produce the lowest VGRF.
Key words: ground reaction force, coordination, transfer, sit-to-stand, mobility

Introduction

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

From the clinical point of view, STS requires the ability to coordinate motion in the desired direction and lower limbs movement; to correct muscle strength, balance control and stability; and to adapt to changing tasks and environmental conditions [4]. Subjects with balance disorders performed the the Five-Times-Sit-to-Stand Test more slowly than those without such syndromes [5]. Longer duration of STS in patients represents a compensatory pattern to address muscle weakness of a lower limb in hemiplegic patients [3].

Characteristic movements engaged in STS are marked by four phases: preparation – flexion, momentum-transfer, extension, and stabilization. The last phase starts when hip extension is reached and ends when all motion associated with postural stability is completed [6, 7].

In healthy individuals, the duration of these phases is comparable, as is the time course and magnitude of forces exerted on the ground. During the common STS manoeuvre, a momentum-transfer strategy is used, based on a trade-off between stability and force requirements and coordination and strength in the 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 centre of mass (COM) well within the base of support of the feet prior to the lift-off. This, however, requires the generation of larger lower-extremity forces in order to lift the body to the vertical position [4].

In 3D kinematic data of the 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 producing the greatest flexion. This extension strategy of segment motion was consistent with the torso joint extension displayed by many of the participants. The 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/pelvic 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

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Received: 27.04.2017
Accepted: 27.06.2017

Citation: Sipko T, Stefanik M, Glibowski E, Paluszak A, Kuczyńsk M. The impact of flexion or extension movement transfer pattern on the performance of sit-to-stand task in asymptomatic young subjects. Physiotherapy Quarterly. 2017;25(1):17–22; doi: 10.1515/physio-2016-0012.

strategy indicates that the higher torso segments were flexing forward and extending somewhat independently of pelvis motion [8].

The component of STS regarded 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 that at the hips' being considered a common motor problem [9].

To the best of our knowledge, there is no analysis of time and events concerning the vertical ground reaction force (VGRF) in the flexion or extension movement transfer pattern. We would like to contribute to the understanding of the role of the lumbar-pelvic movement in the performance of the STS task on the basis of the findings that this area has a crucial kinematic function during the STS movement in healthy subjects [8]. The aim of the study was to assess the mode of the STS task performed in a habitual manner and that performed in flexion or extension pattern transfer in asymptomatic young subjects. It was hypothesized that different initial movements of the lumbar-pelvic area would modify STS performance and display different coordination in the timing and level of VGRF. We would like to explain whether differences in performing the STS task observed within a young population without current musculoskeletal problems indicate various characteristic events of vertical reaction force and the time of phases.

Subjects and methods

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 being asymptomatic (Numerical Rating Scale of pain [NRS] = 0), the age of 22–23 years, no history of chronic low back pain (CLBP), and normal body mass (body mass index [BMI], 18.5–24.9 kg/m^2). BMI was calculated and classified according to standard WHO criteria [10]. The average body mass of the surveyed students was 66.3 ± 13.4 kg, while the average body height equalled 1.75 ± 0.11 m. The exclusion criteria were as follows: neurological disease; orthopaedic 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. 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 manoeuvre. The STS task was repeated three times, with a break as a washout period. The STS movement was performed in a habitual (STS_hab) manner, or with the lumbar spine in flexion (STS_flex) or extension (STS_ext) in the preparation phase. The order of the experimental conditions 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 VGRFs. These events, in the 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 (GRF), the results were normalized:

$$(\text{Force/body weight}) \times 100\%$$

Phases times were analysed in accordance with 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 the stable standing 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) (Figure 1). All measures of force and phases times were used to compare the STS tasks.

Statistical analysis

Power analysis and sample size selection were performed prior to the study. With the assumption of 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 the Statistica 12.5 (StatSoft) software.

The intraclass correlation coefficients ($ICC_{2,1}$) indicated that the measurements of VGRF and events times in STS had high and good reproducibility [11]. The Shapiro-Wilk test indicated that the results concerning the forces and the event

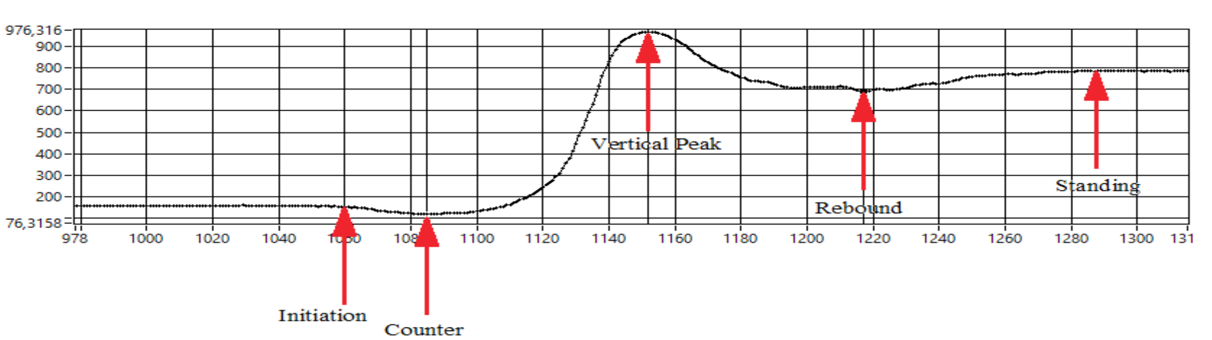

Figure 1. Exemplary raw force recordings

times were normally distributed. ANOVA (3 TASK × 3 EVENT) was applied for main effects, followed by Tukey's post-hoc test.

The mean values and 95% confidence intervals were presented in Figures 2–8. The two-sided alpha level was set at $p < 0.05$.

Results

Total time from sit to stand position

The ANOVA analysis revealed the main effect in the total time of the STS manoeuvre in three STS movements ($F(2, 58) = 30.74$, $p < 0.00001$). The shortest total time of STS was bound with the habitual manner. The post-hoc tests indicated significant differences between the total time of the STS_hab pattern and both STS_flex and STS_ext patterns ($p < 0.05$). There was no difference in the total time between the latter strategies ($p > 0.05$) (Figure 2).

Preparation phase

The ANOVA analysis revealed the main effect in the time to minimum VGRF in three STS movements ($F(2, 58) = 11.102$, $p = 0.00008$). The shortest Tmin of STS was bound with the habitual manner and the flexion pattern. There were no significant differences of time to minimum between the STS_hab and STS_flex patterns ($p > 0.05$). The post-hoc tests revealed significant differences between time to minimum VGRF in the STS_ext pattern and STS_flex and STS_hab pattern ($p < 0.001$) (Figure 3).

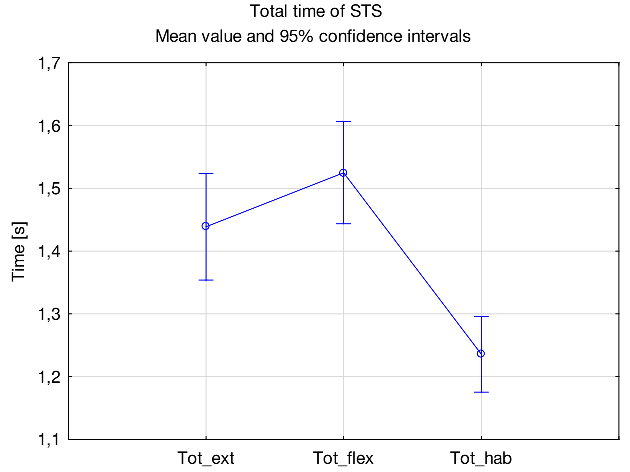

Figure 2. Total time of the sit-to-stand (STS) task performed habitually (Tot_hab), and with flexion (Tot_flex) and extension pattern (Tot_ext)

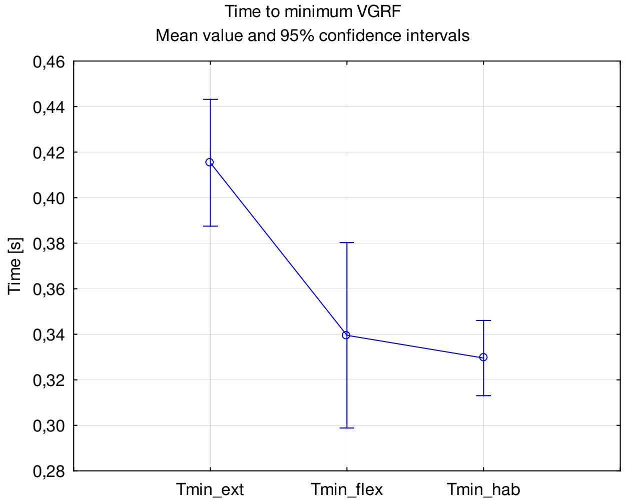

Figure 3. Time to minimum vertical ground reaction force (VGRF) in the sit-to-stand task performed habitually (Tmin_hab), and with flexion (Tmin_flex) and extension pattern (Tmin_ext)

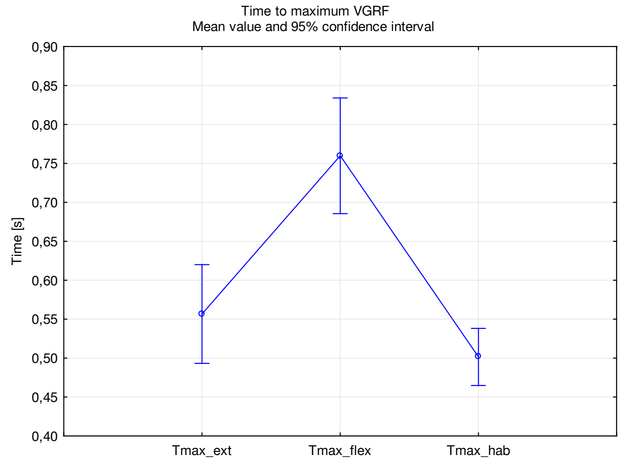

Figure 4. Time to maximum vertical ground reaction force (VGRF) in the sit-to-stand task performed habitually (Tmax_hab), and with flexion (Tmax_flex) and extension pattern (Tmax_ext)

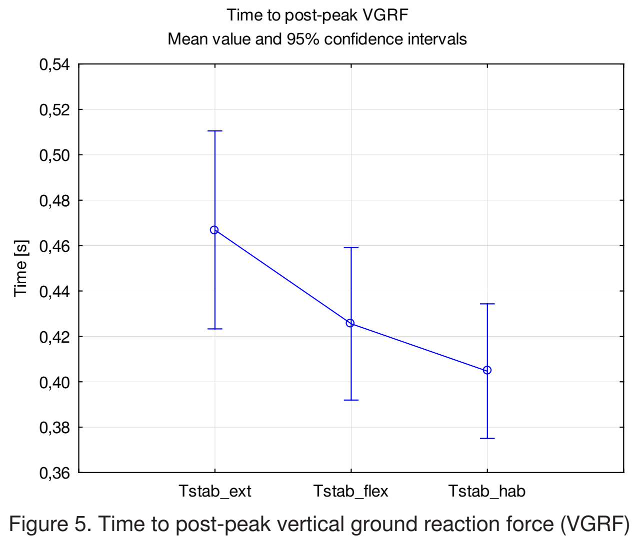

Figure 5. Time to post-peak vertical ground reaction force (VGRF) in the sit-to-stand task performed habitually (Tstab_hab), and with flexion (Tstab_flex) and extension pattern (Tstab_ext)

Extension phase

The ANOVA analysis revealed the main effect in the time to maximum VGRF in three STS movements ($F(2, 58) = 47.117$, $p = 0.00000$). 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 maximum VGRF in the STS_flex and STS_hab and STS_ext ($p < 0.001$). There was no difference between the time to maximum VGRF in the STS_hab and STS_ext (Figure 4).

Stabilization phase

The ANOVA analysis revealed the main effect in the time to post-peak rebound of VGRF in three STS movements ($F(2, 58) = 3.7523$, $p = 0.02935$). The shortest time to post-peak rebound force was identified in STS performed habitually, and the longest time was in STS performed with an

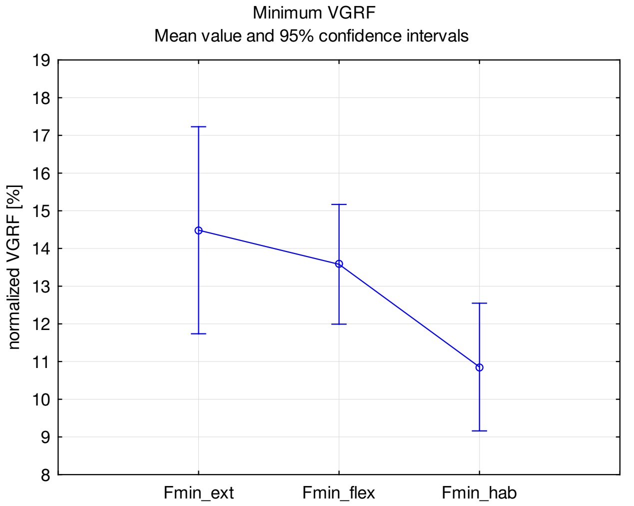

Figure 6. Normalized minimum vertical ground reaction force (VGRF) in the sit-to-stand task performed habitually (Fmin_hab), and with flexion (Fmin_flex) and extension pattern (Fmin_ext)

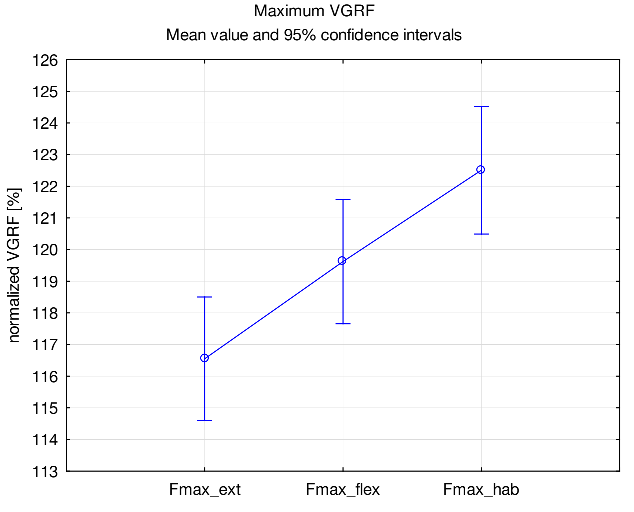

Figure 7. Normalized maximum vertical ground reaction force (VGRF) in the sit-to-stand task performed habitually (Fmax_hab), and with flexion (Fmax_flex) and extension pattern (Fmax_ext)

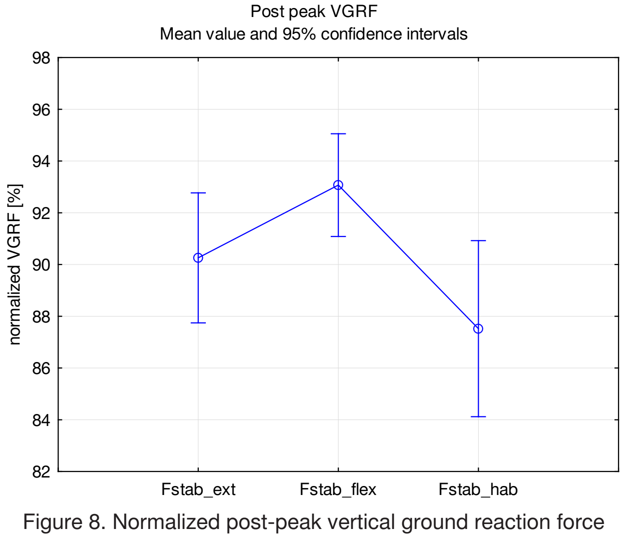

Figure 8. Normalized post-peak vertical ground reaction force (VGRF) in the sit-to-stand task performed habitually (Fstab_hab), and with flexion (Fstab_flex) and extension pattern (Fstab_ext)

extension of the lumbar spine. The only significant difference referred to these two ($p < 0.05$) (Figure 5).

Normalized minimum VGRF

The ANOVA analysis revealed the main effect in the Fmin VGRF of the STS manoeuvre in three movements strategies (F(2, 58) = 14.878, $p = 0.00001$). There were significant differences between the minimum VGRF in the STS_hab and STS_flex and STS_ext ($p < 0.0001$). There was no difference in the minimum VGRF between both latter tasks ($p > 0.05$) (Figure 6).

Normalized maximum VGRF

The ANOVA analysis revealed the main effect in the maximum VGRF in three STS movements (F(2, 58) = 21.670, $p = 0.00000$). The most dynamic performance of STS was identified in the STS_hab pattern, and the least dynamic – in the STS_ext pattern. There were significant differences between the maximum VGRF in the STS_hab pattern and STS_ext ($p < 0.0001$) and STS_flex ($p < 0.01$), as well as between both latter tasks ($p < 0.01$) (Figure 7).

Normalized minimum post-peak VGRF

The ANOVA analysis revealed the main effect in the post-peak VGRF in three STS movements (F(2, 58) = 7.7220, $p = 0.00106$). The stabilization phase in the STS_hab pattern turned out the least dynamic. The only significant difference appeared between the vertical force in the STS_hab and STS_flex patterns ($p < 0.0001$) (Figure 8).

Discussion

It was hypothesized that different initial movements of the lumbar-pelvic region would modify the performance of the STS task and display different coordination in the timing and level of VGRF. The results of the study point at different characteristic events of vertical reaction force and the time of phases which depends on performing the STS task in the young population. Three findings were the most interesting. First, there was no difference in the total time between the flexion and extension mode of STS. Second, there was no difference between the flexion and extension STS task in the minimum vertical GRF during the preparation phase, but the extension STS task was the longest in the preparation time. Third, the most interesting, only this latter pattern was characterized by a similar extension phase as the habitual pattern with the least maximum VGRF.

STS duration varied significantly, from 1.23 s for the habitual to 1.43 s for the extension and 1.53 s for the flexion trials. These values were consistent with the results found in the literature [12, 13]. In the study by Mazza et. al. [13], the average duration of the STS task performed with natural speed was identified at 1.6 s (*SD* = 0.3), with no significant differences associated with the different foot positions. However, in the own study, the total time of STS was impacted by the pattern of STS: new patterns made 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 supported the study of Hamaoui and Alamini-Rodrigues [14], in which experimentally increased muscular tension along the trunk required an adaptation of the early postural activity, termed anticipatory postural adjustments, which became longer to maintain the same level of performance in the STS.

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

The forced new motor strategy to change body position from sitting to standing clearly extended the task time in each stage of STS. It was assumed that flexion and extension patterns were affected by learning. The construction of a new motor activity requires a lot of information processing. Specific solutions of the unusual pattern are regularly developed and tailored. The fastest movements are executed without the possibility of adjustment 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, the situation is opposite. Greater torque in the hip and lower knee affect the GRF value [16].

In the extension phase, the greatest value of the vertical GRF was observed in subjects tested during the habitual pattern. The smallest force of the vertical GRF in this phase was identified in subjects during the extension pattern of STS. It was assumed that the extension pattern of STS could be used in decreasing the VGRF in the general pain population patients. Avoidance behavior in STS execution was presented in CLBP patients, in high pain individuals only, indicating that chronic pain intensity was a significant factor in decreasing ground reaction peak force and increasing time to peak force [11].

The neutral position of a spine in the activity of daily living is recommended for low back patients to decrease the load or eliminate pain in motion [17]. A modification to the STS 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 properly performed STS could be an element of prophylaxis of the back pain problem. Moreover, different disturbances in movements were observed in CLBP patients: delayed anterior pelvic movement in STS [2], lack of synergy between the movements of hip and lumbar spine [19], changes in the kinematics and coordination of the lumbar spine and hips during STS and stand-to-sit [20]. The flexion pattern of STS with the lumbar spine flexed more and the pelvis flexed less could be a reason for repetitive overload in the lumbar spine area soft tissues in the working population. However, data provided 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° for every 3.1° of hip flexion.

During the stabilization phase, the last one of the STS, the subjects presented the least impact on the ground in the habitual pattern of STS. The biggest VGRFs were observed during the flexion pattern of STS. This may result from the largest displacement of the centre of gravity of the body. Not without significance is also the imposition of a new pattern in performing well-known operations. The habitual position of the spine when standing up is a natural position, which was repeated many times. This affects the smoothness of the task. This ability is acquired through training. The learning and improvement of new motor patterns are supported by the plasticity of the nervous system [21]. Only repeating the new task causes the formation of new connections between neurons and the consolidation of the transition [22].

Limitation

The study had a number of limitations. The results cannot apply to the muscle activity or pelvis-lumbar spine kinematics, which was not controlled during the STS tasks. The range of the pelvis-lumbar spine motion is one of the factors involved in the STS movement, and its contribution should be clarified in future research. The study was performed only among young, asymptomatic subjects and therefore the results cannot be addressed to CLBP patients or elderly subjects.

Conclusion

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

Conflict of interest statement

The authors state no conflict of interest.

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