

EFFECTS OF DEFICIT OF STRENGTH IN THE SIT-TO-STAND TASK IN PEOPLE WITH MULTIPLE SCLEROSIS

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ABSTRACT

To assess how the deficit of static strength associated with neurological and functional alterations caused by multiple sclerosis (MS) affects sit-to-stand (STS) performance. A comparative analysis of STS performance was conducted in four groups. 20 persons with MS, with an EDSS score <6.5, were divided into two groups based on sex and static strength of leg extensor muscles. Twenty healthy controls were allocated to another two groups based on the same criteria. STS performance was assessed by measuring ground reaction forces and 2D photogrammetry. Participants with MS exhibited similar static strength that control groups, only in those persons with higher Expanded Disability Status Scale the deficit was higher. However, MS groups show lower dynamic strength during muscle extension in the STS task. This effect could be related to other alterations associated with MS such as postural control and coordination impairment. The MS sample with deficit of static strength took longer to perform the STS task ($p < 0.001$), being the deceleration period the one that most contributed to delay ($p < 0.001$). Although the static force is similar between groups with MS vs Controls groups, performance of the STS task is altered by dynamic strength weakness and postural control and coordination factors that are related with the level of disability reported by MS through the EDSS scale.

Keywords: motor control, biomechanics, multiple sclerosis, sit-to-stand task

EFEECTO DEL DÉFICIT DE FUERZA EN LA TAREA SIT-TO-STAND EN PERSONAS CON ESCLEROSIS MÚLTIPLE

RESUMEN

El propósito de este estudio ha sido evaluar el efecto del déficit de fuerza estática provocado por las alteraciones neurológicas y funcionales debidas a la esclerosis múltiple (EM), comparando los factores de eficacia de la tarea sit-to-stand (STS) entre cuatro grupos equivalentes en edad, sexo, hábitos socioculturales y estructura corporal. Han participado 20 personas diagnosticadas con EM (10 hombres y 10 mujeres), asignadas a dos grupos según sexo y magnitud de su fuerza extensora estática y 20 sujetos control libres de patologías (10 hombres y 10 mujeres), asignados a otros dos grupos según el mismo criterio. Para la evaluación del rendimiento de la tarea STS, se han registrado las componentes de la fuerza de reacción, utilizando para ello una plataforma de fuerzas, a partir de las cuales se obtuvieron los respectivos registros de las velocidades del CM, mediante integración. Para la determinación de la cinemática angular se han utilizado técnicas fotogramétricas (2D) y un modelo simplificado de tres segmentos. La sincronización temporal de los registros se ha realizado mediante un sistema electrónico. Los resultados han sugerido la existencia de un cierto déficit de fuerza estática debido al incremento del nivel de discapacidad propio de la EM, pero no en todos los casos. Además del nivel de la fuerza estática, los datos han puesto de manifiesto que la fuerza dinámica extensora, desarrollada durante la tarea STS, podría estar relacionada con otros factores asociados a la esclerosis múltiple, como son los problemas de control postural y coordinación. El grupo con EM y déficit de fuerza estática, tarda más en realizar la tarea STS ($p < 0.001$), siendo el periodo de frenado el que contribuye en mayor grado de este retardo ($p < 0.001$). Se podría afirmar que la tarea STS es un buen predictor de la evolución de la enfermedad, aunque la causa no siempre sea debida al déficit de fuerza. Además, es necesario considerar los problemas de coordinación y alteración del equilibrio, característicos de esta enfermedad.

Palabras clave: control motor, biomecánica, fuerza, esclerosis múltiple, tarea sit-to-stand

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INTRODUCTION

Multiple sclerosis (MS) is a demyelinating disease by which the messages that travel along nerves are slowed, thereby causing functional and motor impairment¹. Structural and neurological alterations have been documented in people with MS, with impact on muscle strength and motor coordination^{2,3,4}. The measures most commonly investigated include peak strength (PF), peak power (PP) and rate of force development (RFD) in relatively slow or isokinetic dynamic tasks involving the extensor muscles of the lower limbs⁵. Deficit of strength caused by MS often compromises balance and postural control and negatively affects performance of daily tasks such as walking, climbing the stairs or raising from a chair^{6,7,8}.

The sit-to-stand (STS) task has been traditionally used to assess deficit of strength and balance and coordination alterations in patients with functional and/or motor impairment. There is consistent evidence that STS performance is a good indicator of functional and motor impairment in obese and elderly people^{9,10,11}. Bowser, O'Rourke, Brown, White and Simpson (2015)¹² have compared STS performance between MS patients and controls; participants with MS were selected on the basis of peak leg extensor strength in dynamic activity. According to the authors¹², participants with multiple sclerosis exhibiting leg weakness took longer to stand and appeared to use a trunk-flexion movement strategy when performing the sit-to-stand.

Yet, the deficit of strength exhibited by MS participants is not only due to the functional alterations caused by the disease, but also to physical inactivity and the lack of specific training¹³. In this sense, strength and neural drive have been reported to improve in MS patients who participate in training programs^{13,14}. Whether deficit of strength is caused by alterations secondary to MS, physical inactivity or both is still unclear. Nevertheless, healthy controls participating in studies may also exhibit some deficit of strength due to physical inactivity⁴.

The purpose of this study was to evaluate the deficit of strength secondary to the neurological and functional alterations caused by MS on the STS biomechanics, among four different groups: two groups of people with MS one of them who show deficit on the static strength of leg extensor muscles and two control groups who do not have MS, one of this group also exhibit weakness on the static strength. Considering the factors exposed above, we postulated that: a) MS and control groups without deficit strength would have a similar static strength, whereas the MS and the control groups with deficit would have a similar deficit of strength; b) MS participants with deficit of strength would exhibit a poorer mean performance of the STS task, as compared to the other three groups. Differences between MS participants with deficit of strength and

controls with deficit of strength would be associated with neurological alterations, balance impairment and risk of falling associated with this disease.

METHOD

Participants

The sample was composed of 20 patients with multiple sclerosis (10 men and 10 women). Inclusion criteria were: a) a confirmed diagnosis of MS with an EDSS score <6.5; b) ability to perform the sit-to-stand movement; c) no history of surgery or fracture in the lower limbs in the last year; and d) absence of MS flare-ups within the last six months.

All participants completed an analysis of body composition by the InBody-230 system. Based on general data and previous medical examinations, 20 healthy participants with full motor and cognitive function were allocated to the control sample (10 men and 10 women). Sample matching in terms of age, sex, sociocultural habits and body structure was performed using stratification and proportional allocation methods.

Once static strength was measured, each sample (MS and controls) was divided into two groups based on sex and peak of strength. MS participants with a static strength below the mean of sex-matched MS participants were allocated to the MS group with lower static strength (MS-LS). The other MS participants were assigned to the higher-static-strength MS group (MS-HS). Controls with a peak of strength below the mean of sex-matched controls were allocated to the lower-static-strength control group (CON-LS). The other participants were assigned to the higher-static-strength control group (CON-HS). In accordance with the guidelines of the Ethics Committee of the University, informed consent was obtained from all participants. Table 1 displays descriptive and inferential statistics for mean values in the four groups. Peak of force is expressed as normalized values with respect to body mass.

TABLE 1
Descriptive characteristics of the participants in the four experimental groups.

Variable	MS		CONTROL		<i>f</i>
	Group 1: MS-LS	Group 2: MS-HS	Group 3: CON-LS	Group 4: CON-HS	
	Mean SD	Mean SD	Mean SD	Mean SD	
Age (years)	42.0 ± 7.3	40.4 ± 5.1	47.8 ± 5.5 ²	46.6 ± 10.6	2.19
Height (m)	1.69 ± 0.10	1.72 ± 0.07	1.70 ± 0.09	1.67 ± 0.09	0.64
Mass (kg)	74.3 ± 18.3	72.2 ± 6.3	75.0 ± 10.5	65.3 ± 13.6	1.17
Muscular Mass (kg)	26.9 ± 7.1	30.7 ± 1.9	31.2 ± 7.3	26.9 ± 5.8	1.33
Muscular Mass (%)	37.0 ± 4.3	42.9 ± 5.5 ¹	40.6 ± 5.3	42.2 ± 4.2 ¹	2.41
Fat Mass (kg)	22.6 ± 6.6	17.8 ± 7.7	20.7 ± 6.8	15.2 ± 6.1 ¹	1.94
Fat Mass (%)	31.1 ± 5.5	23.2 ± 8.9 ¹	27.3 ± 8.4	23.6 ± 7.0	1.93
Body Mass Index (kg/m ²)	24.2 ± 3.0	25.1 ± 4.1	26.4 ± 3.2	23.0 ± 3.2 ³	1.73
Peak of force (PF) (N/N)	1.89 ± 0.32	2.38 ± 0.28 ¹	1.77 ± 0.29 ²	2.46 ± 0.47 ^{1,3}	9.51 ^{***}
EDSS	4.25 ± 1.68	2.40 ± 1.26 ¹	-	-	7.7 ^{**}

*** $P < 0.001$; ** $P < 0.01$ ^{1,2,3} indicate significant differences between the groups ($P < 0.05$).

Materials and measurement systems

The equipment used included two Dinascan/IBV 0.6 x 0.37 m. force plates (Instituto de Biomecánica de Valencia, Spain) set at 200 Hz. The surface of one of the plates was extended by attaching a wooden platform (0.6 x 0.9 m) on which a height-adjustable seat was installed ¹⁶. After adjustments were made, captures were set at 0. The other force plate was placed in front of a force tower fixed to the floor which had a height-adjustable horizontal bar. Kinematic data were acquired by photogrammetry (2D) using a video camera (JVC GC-PX100_{BE}) set at 200 Hz and a modular photogrammetry system designed ad hoc for this study (Cyborg V. 3.0). The synchronization of measurements was achieved by means of an electronic signal that activated a LED light placed within the field of view of the video camera when the force plate started to send data.

Procedures

Participants were allocated to four groups on the basis of their peak static strength. To such purpose, after active warm-up, participants stood on the force plate with the horizontal bar of the force tower positioned in front of them at a height of 120% the distance of the knees from the ground (medial epicondyle). Participants were instructed to flex slightly the trunk in an upright position, grip the bar, and stay in that position until the signal was delivered; when the LED light turned on, they had to rapidly pull up the fixed bar. After several practice repetitions to acquire the appropriate technique, participants performed five valid trials every twenty seconds to avoid fatigue. The vertical component of ground reaction forces was measured; peak strength was the

median of peak strength values reached in the five trials (PF_S). Figure 1A shows a simplified scheme of the test.

To perform the sit-to-stand (STS) trial, participants were instructed to sit on the seat, which height was adjusted to a height of 80% the distance between the knees and the ground (head of the fibula) with their arms folded on their chest, the trunk in upright position and the feet parallel on the plate. When the signal was delivered, participants had to stand up rapidly without raising the shoulders or moving their feet and stay motionless when they reached a vertical position¹⁶. Following some trials, participants were allowed to adjust the position of their feet in order to accommodate their natural stance. The mean angle of legs was (θ_{LEG}) $67^{\circ} \pm 4^{\circ}$, without statistically significant differences across groups. The vertical (F_y) and horizontal (F_x) component of ground reaction forces were measured in the five valid trials every twenty seconds to avoid fatigue. We only considered for analysis the trial where STS time matched the median STS time of the five trials.

To simplify the measuring of angular kinematics, the STS task was approached as a symmetrical movement performed in the sagittal plane. This allowed us to use a simplified coordinated model of three segments (trunk, thighs and legs) marked by four sensors placed on the body of participants (ankle, knee, hip and shoulder). The video camera was installed perpendicular to the sagittal plane of the movement where a reference system was fixed. Figure 1B shows a schematic representation of the model and angle measurements.

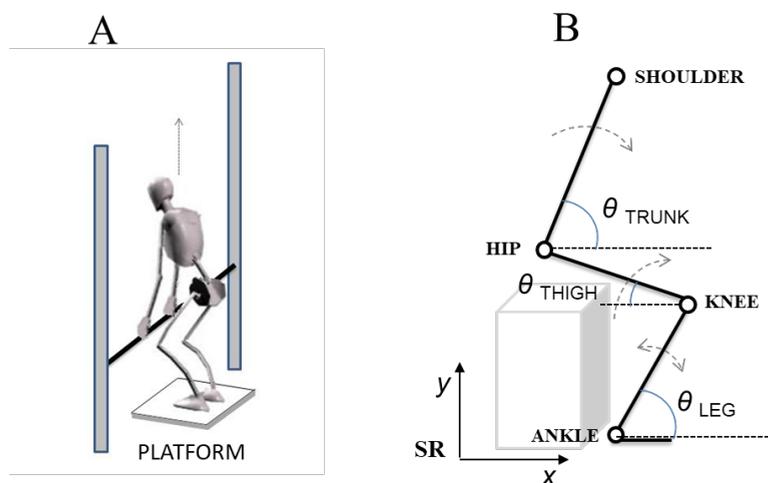


FIGURE 1: Schematic representation of the static strength test (A) and angular kinematics of the STS task (B).

Data analysis

Center of mass (CM) velocities were calculated from the respective reaction force components as measured by the force plate. First, body weight was subtracted from the vertical component (F_Y). Then, vertical and horizontal acceleration was calculated on the basis of the respective force components and body mass. The vertical and horizontal component of velocity ($v_{Y(CM)}$ and $v_{X(CM)}$, respectively) were determined by integration of acceleration-time functions using the trapezoidal method with a time increase of 0.005 s. The constant of integration was 0. Peak strength was calculated from the horizontal and vertical reaction force components ($PF_{(X)}$ and $PF_{(Y)}$, respectively) and rate of force development of the vertical component ($RFD_{(Y)}$), defined as the ratio between 30% of $PF_{(Y)}$ and the time required to reach the $PF_{(Y)}$ from the minimum force prior to force increase (figure 2).

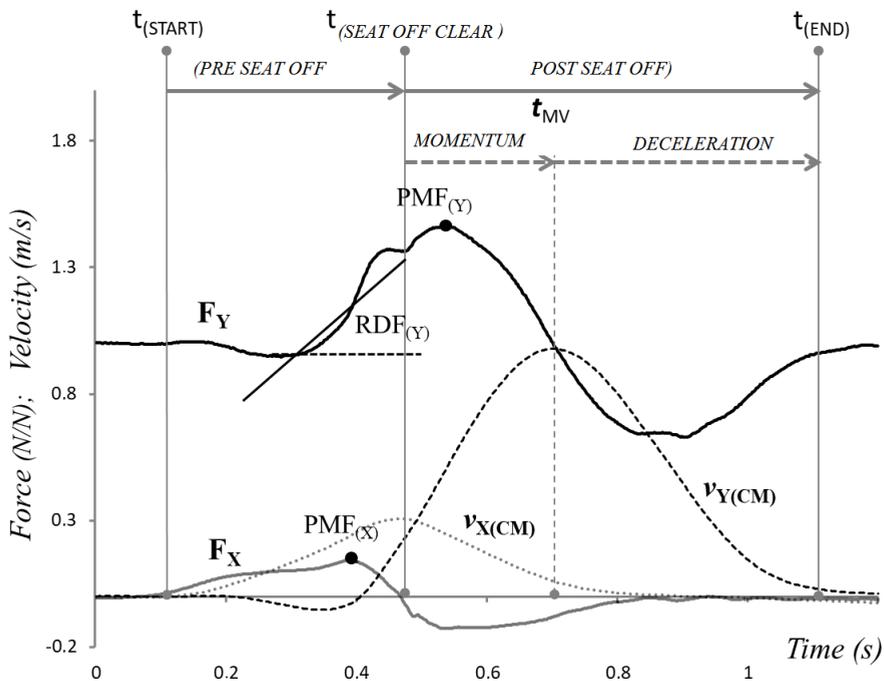


FIGURE 2: Schematic representation of STS phases based on reaction force components (F_Y and F_X), CM velocity components ($v_{Y(CM)}$ and $v_{X(CM)}$), peak strength values (PS) and rate of force development (RFD) for one of the participants.

Sagittal-plane coordinates for the four sensors representing a simplified human model were derived from manual digitization (at 50 Hz) of the video. Next, interpolation to 200 Hz was performed using a Quintic smoothing spline of 0.0001¹⁷. Finally, conversion with respect to reference system was

performed. The sequential angular positions of the three segments were determined by the inner product of their respective position vectors with respect to the horizontal axis. The angular velocity of each segment was calculated from the first derivative of the respective angular positions with respect to time by a fifth degree spline.

Analysis of STS time ($t_{\text{STS TASK}}$) was based on three events: *a) Start of the task* (t_{START}), defined as the moment where the net force of the horizontal or vertical component was $\geq 1\%$ of body mass¹⁸; *b) Seat-off* ($t_{\text{SEAT-OFF CLEAR}}$), defined as the moment where the thighs lost contact with the front edge of the seat, as identified from the video recording; and *c) End of task* (t_{END}), defined as the moment where extension is completed and the CM vertical velocity of the CM ($v_{Y(\text{CM})}$) is $\leq 0.05 \text{ m}\cdot\text{s}^{-1}$. Two time intervals were defined based on whether the participant was in contact with the seat or not ($t_{\text{PRE-SEAT-OFF}}$ and $t_{\text{POST-SEAT-OFF}}$, respectively). For a more detailed analysis, the phase following the seat-off phase ($t_{\text{POST-SEAT-OFF}}$) was further divided into two intervals: *a) Momentum*, which extends from $t_{\text{SEAT-OFF}}$ to the point where the vertical velocity of the CM reaches its maximum value (t_{MV}) and *b) Deceleration*, which is the interval between t_{MV} and t_{END} . Figure 2 shows events and their respective intervals as well as the vertical and horizontal components of force normalized with respect to body mass ($F_{(Y)}$ and $F_{(X)}$, respectively) and the respective velocity components of the CM ($v_{Y(\text{CM})}$, $v_{X(\text{CM})}$) for each participant.

Statistical analysis

Means and standard deviations (SD) were calculated for each variable in each sample. Differences between means (MS-LS, MS-HS, CON-LS, CON-HS) were determined by independent-measures analysis of variance (ANOVA) and statistical hypothesis testing for multiple comparisons. The potential correlation between peak static strength and level of disability –as assessed by EDSS– was determined using the linear correlation coefficient for data from the MS sample. Test reliability was determined for the four groups by repeated-measures analysis of variance of all valid trials (five valid trials per participant). STS time ($t_{\text{STS TASK}}$) was used as dependent variable, without statistically significant intra-subject differences. In the MS sample, intra-class correlation coefficient values were 0.912 ($p < 0.001$) and 0.916 ($p < 0.001$) for the MS-LS and MS-HS group, respectively. In the control sample, correlation coefficient values were 0.987 ($p < 0.001$) and 0.972 ($p < 0.001$) for the CON-LS and CON-HS group, respectively.

RESULTS

Table 2 contains descriptive and inferential statistics for time parameters in the STS task. The results obtained indicate that the time needed by MS participants with deficit of static strength (MS-LS) to perform the STS task (STS

time) was significantly higher as compared to the other groups ($p < 0.001$). Of note, no statistically significant differences were observed between the other groups. Differences remained significant in the two phases of the task (pre seat-off/post seat-off), although differences were more significant in post seat-off time ($p < 0.01$ and $p < 0.001$, respectively). Delay in the post seat-off phase (momentum and deceleration) in the MS-LS group was due to the longer time needed by these participants to complete the deceleration phase ($p < 0.001$).

Table 2 shows statistics for peak strength values of the horizontal and vertical components of reaction forces and the rates of vertical force development ($RFD_{(Y)}$) for the four groups. All force data were normalized with respect to body mass. Mean $PF_{(X)}$ was significantly lower in the MS group with deficit of strength (MS-LS) as compared to the other groups ($p < 0.001$). More significant differences were observed between the MS sample and controls in the vertical component (Peak Max. Force $_{(Y)}$; $p < 0.001$), being higher in controls. Mean rates of vertical force development $RFD_{(Y)}$ was higher in the control sample compared to the MS sample. Yet, differences were only significant between the MS-LS and the other groups ($p < 0.05$).

TABLE 2
Descriptive and inferential statistics for time and reaction force parameters in the four groups.

Variable	MS		CONTROL		f
	MS-LS	MS-HS	CON-LS	CON-HS	
	Mean SD	Mean SD	Mean SD	Mean SD	
Sit to Stand task time (s)	1.43 ± 0.44	0.90 ± 0.09 ¹	0.89 ± 0.09 ¹	0.84 ± 0.10 ¹	14.21***
Time pre-take off chair (s)	0.52 ± 0.17	0.36 ± 0.06 ¹	0.39 ± 0.07 ¹	0.36 ± 0.05 ¹	5.91**
Time pos-take off chair (s)	0.91 ± 0.28	0.54 ± 0.05 ¹	0.50 ± 0.08 ¹	0.48 ± 0.07 ¹	17.63***
Time of propulsion (s)	0.33 ± 0.12	0.29 ± 0.06	0.26 ± 0.06 ¹	0.23 ± 0.05 ¹	3.07*
Time of deceleration (s)	0.58 ± 0.29	0.26 ± 0.05 ¹	0.24 ± 0.05 ¹	0.25 ± 0.05 ¹	11.76***
Peak Max. Force $_{(X)}$ (N/N)	0.12 ± 0.05	0.22 ± 0.06 ¹	0.20 ± 0.04 ¹	0.18 ± 0.02 ¹	9.52***
Peak Max. Force $_{(Y)}$ (N/N)	1.18 ± 0.14	1.40 ± 0.11 ¹	1.57 ± 0.13 ^{1,2}	1.52 ± 0.14 ^{1,2}	17.31***
Rate Force D. $_{(Y)}$ ((N/N)/s)	1.46 ± 0.77	2.28 ± 0.78	2.70 ± 1.23 ¹	2.95 ± 1.15 ¹	4.23*

*** $P < 0.001$; ** $P < 0.01$ * $P < 0.05$ ^{1,2,3} indicate significant differences between the groups ($P < 0.05$).

Table 3 shows descriptive and inferential statistics for STS kinematics. In relation to the linear kinematics of the center of mass (CM), slight differences were observed in the minimum value of the vertical velocity component of the CM ($Min v_{and (CM)}$; $p < 0.05$). The horizontal velocity of the CM at seat-off ($v_{X(CG) TAKE OFF CHAIR}$) was higher in the MS-HS group, although (slight) differences among the four groups were only found in mean values ($p < 0.05$). Similar results were obtained in relation to the horizontal velocity of the CM ($Max v_X (CM)$), which indicates that seat-off is close to $Max v_X (CM)$. The vertical velocity component of the CM at seat-off ($v_{Y (CG) SEAT-OFF}$) was significantly higher in

controls than in MS participants ($p < 0.01$). The mean maximum vertical velocity of the CM during STS ($Max v_{Y(CM)}$) was lower in the MS-LS), compared to the other groups ($p < 0.001$).

TABLE 3
Descriptive and inferential statistics of the linear kinematics of the CM and the angular kinematics of the trunk and legs.

Variable	MS		CONTROL		f
	MS-LS	MS-HS	CON-LS	CON-HS	
	Mean SD	Mean SD	Mean SD	Mean SD	
$Min v_{Y(CM)}$	-0.06 ± 0.02	-0.03 ± 0.02^1	-0.07 ± 0.03^2	-0.05 ± 0.02	3.88*
$v_{X(CM)}$ TAKE OFF CHAIR (m/s)	0.27 ± 0.16	0.42 ± 0.11^1	0.36 ± 0.04	0.33 ± 0.05	3.73*
$v_{Y(CM)}$ TAKE OFF CHAIR (m/s)	0.13 ± 0.12	0.18 ± 0.11	0.28 ± 0.09^1	$0.30 \pm 0.09^{1,2}$	5.91**
$Max v_{X(CM)}$ (m/s)	0.30 ± 0.13	0.42 ± 0.10^1	0.37 ± 0.05	0.33 ± 0.06	3.77*
$Max v_{Y(CM)}$ (m/s)	0.66 ± 0.18	0.92 ± 0.10^1	1.01 ± 0.25^1	0.98 ± 0.18^1	7.08***
θ_{TRUNK} TAKE OFF CHAIR ($^\circ$)	56 ± 8	64 ± 3^1	69 ± 5^1	68 ± 7^1	8.62***
θ_{THIGH} TAKE OFF CHAIR ($^\circ$)	27 ± 3	24 ± 2	27 ± 2	25 ± 4	2.62
Max trunk flexion ($^\circ$)	52 ± 8	61 ± 3^1	66 ± 5^1	66 ± 6^1	10.96***
Max trunk flexion velocity (rad/s)	-1.76 ± 0.42	-1.88 ± 0.33	$-1.36 \pm 0.18^{1,2}$	-1.53 ± 0.4^2	4.23*
Max thigh extension velocity (rad/s)	1.95 ± 0.51	3.29 ± 0.32^1	3.31 ± 0.84^1	3.04 ± 0.42^1	13.13***

*** $P < 0.001$; ** $P < 0.01$ * $P < 0.05$ ^{1,2,3} indicate significant differences between the groups ($P < 0.05$).

Regarding angular kinematics, trunk flexion at seat-off ($\theta_{SEAT-OFF}$) was higher in the MS-LS group as compared to the other groups ($p < 0.001$), while no statistically significant differences were observed among the other groups. Similar data were obtained for maximum trunk flexion during STS (Max trunk flexion; $p < 0.001$). There were no statistically significant differences among groups in thigh flexion at seat-of ($\theta_{THIGH SEAT-OFF}$). Table 3 shows the most significant findings made in relation to trunk and thigh angular velocities during STS. The MS sample exhibited a higher maximum trunk flexion angular velocity than controls ($p < 0.05$). Maximum angular velocity of thigh extension was lower in the MS-LS group, compared to the other groups ($p < 0.001$).

DISCUSSION

Static strength and EDSS scale

As expected, peak static strength was lower in the groups with deficit of force as compared to the groups with greater static strength (21% and 28% for the MS and control sample, respectively). These results were foreseeable, as participants were divided into groups based on their peak static strength (see table 1). Yet, no statistically significant differences were observed between groups with similar static strength. This suggests that the two samples exhibited a similar deficit of static strength. This finding could lead us to dismiss the idea that MS is associated with a specific deficit of strength. However, the MS group with higher disability –as assessed by EDSS– showed a

significantly greater deficit of strength than the group with higher static strength (4.25 ± 1.68 vs 2.40 ± 1.26 ; $p < 0.01$). Based on these data and the weak correlation observed between EDSS scores and peak of static force ($R = -0.46$; $p < 0.05$), a potential relationship may exist between MS-induced disability and deficit of strength. Our results are consistent with those reported by Bowser et al., (2015), who found that not all patients with MS have muscular weakness, which demonstrates how unpredictable MS is ¹.

Dynamic force in the STS task

In general, peak horizontal and vertical reaction force components during STS were lower in the MS-Low Strength group as compared to the other groups (see Table 2). In contrast, no statistically significant differences were observed in means between control groups (CON-LS and CON-HS). This is suggestive that the magnitude of the peak static strength had no effect on maximum reaction force component values during STS. Although differences in the rate of vertical force development were less significant (RFD_y), they still support this hypothesis. The results obtained in this study suggest that both, peak static strength and the magnitude of dynamic force used during STS might be related to other factors associated with MS because the dynamic strength peaks are significantly lower in people with MS with respect to control groups. Such factors include neural activity deficit, problems of postural control, and impaired coordination of partial impulse by body segments during complex movements such as STS ¹⁹.

Analysis of STS time

Time analysis revealed that the MS group with deficit of static strength (MS-LS) took longer to perform the STS task. Delay in the MS-LS group was due to the increased duration of the two phases in which the task was divided ($t_{\text{PRE-seat-off}}$ and $t_{\text{POST-seat-off}}$). However, the post seat-off phase was the one that contributed the most to STS delay. More specifically, the period after the maximum vertical CM velocity was reached (*Deceleration*) was the one with the greatest impact. The reason is that the transition phase where a subject raises from a seated to a standing position after an initial acceleration requires significant postural control¹⁰. The results obtained support the theory that MS people with deficit of strength need more time to execute the post seat-off phase not only because of hip and knee extensor weakness, but also because of a diminished peak static strength. This theory is consistent with the results reported by Bowser et al., (2015), who suggest that individuals with MS that have strength deficits do display some of the trunk-flexion strategy compensations. Only a few studies have been performed to assess STS performance in MS patients. Fujimoto & Chou (2012) compared young MS

patients with older MS patients and found that older people had more difficulties in maintaining postural control at the end of the STS task. This is in agreement with our results, as it confirms a longer duration of the deceleration phase in MS participants with deficit of strength.

Linear kinematics of the CM and angular kinematics of the trunk and lower limbs.

Center of mass (CM) kinematics showed that CM reached negative values in all groups during the pre seat-off phase, which is due to, in part, trunk flexion. In this sense, the MS-LS group exhibited a higher trunk flexion angle as compared to the other groups. The same finding was reported by Bowser et al., (2015), who compared MS people with controls, and by other authors comparing young and elderly MS people²⁰, and obese and normal-weight people¹⁰. Trunk flexion during the pre seat-off phase favors CM displacement towards the double support base and reduces knee extensor momentum²¹. This also causes the trunk to be more flexed and CM vertical velocity to be lower during seat-off ($\theta_{\text{TRUNK SEAT-OFF}}$ and $v_{Y(\text{CG}) \text{ SEAT-OFF}}$, respectively (see table 3). In the initial position, trunk extension during acceleration in the post seat-off phase would increase the reaction force transmitted to the ground by the lower limbs¹². This compressive force may excessively increase knee extensor momentum in people with deficit of static strength. This situation may cause the subject to sequentially perform knee and trunk extension instead executing a simultaneous movement of extension to take advantage of the momentum of the pre seat-off phase, as suggested by Bowser et al., (2015). This model results in a lower CM vertical velocity during the post seat-off phase (see table 3).

Based on the results obtained, the use of a sequential model can only be explained for the MS group with deficit of strength. However, our data do not explain this model in the CON-LS sample, which deficit of static strength was similar to that of the MS-LS group. This inconsistency might be related to the higher CM acceleration during the pre seat-off phase, which does not involve excess trunk flexion⁹. This is supported by the higher CM velocities and lower trunk flexion angles observed in this group during the seat-off phase (see table 3). Balance impairment and risk of falling are likely to limit the use of this model in some MS patients due to their inability to perform enough postural control when rising from a seat to a standing position.

CONCLUSIONS

Deficit of static strength as measured from peaks of strength was similar in the MS and controls samples, which rejects the hypothesis that MS is associated with a specific deficit of static strength. However, the MS sample with force deficit had higher EDSS scores, which were weakly correlated to peak of static

force ($R=-0.46$; $p<0.05$). These results suggest that MS cause some degree of deficit of strength, although this does not occur in all cases.

The MS group with deficit of static strength took longer to perform the STS task ($p<0.001$), being the deceleration period during the post seat-off phase the one that most contributed to delay. This period requires an adequate control of initial momentum and balance; therefore, impaired coordination and balance, and the risk of falling are in part the cause that MS people require more time to perform the STS task. These problems combined with the deficit of strength exhibited by some MS patients would explain that they use a sequential model of segment motion instead of a simultaneous model that takes advantage of the initial momentum.

Analysis of STS biomechanics suggests that the magnitude of dynamic strength during STS might be related to factors associated with MS such as postural control and coordination problems, and the risk of falling. The results of this study indicate that people with MS should undergo specific tests –such as the Sit&Stand test– that require interaction between coordination, postural control, and dynamic strength. This will provide a general picture of the course of the disease due to the correlation shown of the level of disability reported by MS through the EDSS scale and the STS performance.

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