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ORIGINAL ARTICLE

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Immediate effects of postural repositioning on maximum phonation duration tasks in seated individuals with acquired dysarthria: a pilot study

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ABSTRACT

Purpose: To determine the effectiveness of a single 10-min postural repositioning session on the maximum phonation duration (MPD) of the vowel/a/in individuals with acquired dysarthria.

Materials and methods: A pre-post interventional design was implemented; five patients with dysarthria (PWDs) underwent a single 2-hour experimental session. MPD capacities were assessed before and immediately after a 10-min postural repositioning intervention by a physical and occupational therapist. Five age- and sex-matched individuals without dysarthria were recruited as controls. The main outcome measure was the MPD of the vowel/a/at conversational and louder voice levels, with a speech-and-language therapist standing 1 and 6 m away, respectively. Secondary outcome measures were thoracic expansion, manometry, electromyographic recordings of axial muscles and perceived effort.

Results: In PWDs, postural repositioning improved the MPD during the/a/–1-m (80.3% increase) and/a/–6-m tasks (18% increase), increased thoracic expansion and manometric measurements, and reduced the perceived effort necessary to perform the tasks. A triphasic electromyographic pattern was observed during both/a/–1-m and/a/–6-m tasks in controls, but was absent in participants with severe dysarthria, even after postural repositioning. Nonetheless, postural repositioning enabled an earlier onset of EMG activity prior to voice production.

Conclusions: These data suggest the efficacy of postural repositioning in improving phonatory capacities essential for voice production in PWDs.

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Introduction

Dysarthria is a neurogenic speech disorder characterized by abnormalities in the strength, speed, range, steadiness, tone, or accuracy of movements required for breathing, phonatory (i.e., voice production), resonatory, articulatory, or prosodic aspects of speech production [1]. Recent studies have estimated the incidence of dysarthria to be 42% after first-ever ischemic strokes [2] and 10–60% after traumatic brain injuries [3]. The impact of dysarthria goes beyond communication, with potential negative effects on social participation, psychological well-being, and quality of life [4] persisting for several years after the acquired brain injury [5]. To date, there are no clear directives guiding clinical practice, and despite increasing evidence directing treatment strategies, research remains limited and predominantly consists of case studies or case series [4,6,7].

The majority of deficits in dysarthria are largely due to sensorimotor deficits such as weakness or paralysis, incoordination, involuntary movements, and excessive, reduced, or variable muscle tone, which can disrupt respiratory and phonatory systems; and one of the basic measures used for the evaluation and treatment of patients is the maximum phonation duration (MPD) [1]. The treatment of respiratory and phonatory dysfunctions is often prioritized because improvements at this level are believed to lead to improvements in other aspects of speech, such as loudness variation and phrases length [8–10]. Nevertheless, it remains unclear how to best provide rehabilitation for individuals with respiratory and phonatory dysfunctions.

In recent years, several approaches have emerged as potential rehabilitation strategies for acquired dysarthria, including the Lee Silverman voice treatment (LSVT LOUD®), which focuses on increased voice loudness [9,11]; La Trobe University Smooth Speech Program, which focuses on a softer voice [12]; and "Be Clear" therapy, which allows for more latitude in the degree of loudness asked [13]; individually tailored behavioral techniques using a multiple speech subsystems approach [1,4,10] and "Living with Dysarthria" [14], a communication-oriented approach with conversation group therapy and communication partners, have also been suggested. Finally, the Facial oral tract therapy (F.O.T.T.) [15,16] is a neurophysiological approach, including postural control based on the Bobath concept, for patients with breathing and voice difficulty caused by neurological conditions. However, none of these approaches have been demonstrated to be superior to others in patients with brain injury and dysarthria [6]. Thus, speech therapists still chiefly base their practice on professional experience, published case studies, expert opinion [4,7], and client satisfaction [5,15,17].

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One overlooked element that is probably of paramount importance for voice production is postural control. Indeed, a prior study on the singing voice in healthy participants revealed a relationship between postural alignment and improvements in voice parameters, such as voice range and loudness [18]. Staes et al. showed that the respiratory capacities and voice production of a professional singer were improved by specific postural adjustments, including lumbopelvic support, cervical alignment, and head positioning [19]. Hence, posture and voice are closely linked, and cervical, thoracic, and lumbopelvic muscles are likely activated to ensure both postural stability and voice production [20]. As the majority of dysarthric individuals present with deficits in postural control and postural instability [1,11,15,16], the use of these hybrid muscles to increase stability may compromise speech production [15,21]. Speech therapy may, therefore, be more beneficial if the postures of the head, trunk, and pelvis are optimized to enable better muscular activation, resulting in improved respiratory pattern and voice production [15,20,22].

Despite the importance of postural control in voice production, investigations of the effects of postural alignment on speech production efficiency in the dysarthric population are lacking [5,6], with the exception of a single case report [15], which suggested that posture modification can improve speech production efficiency. Several authors have recommended joint therapy with speech-and-language pathologists (SLPs) and occupational therapists to ensure an optimal posture for speech therapy [1,10,20]; nevertheless, clear guidelines for optimal postural repositioning are lacking [4,6,7].

The presence of a specific muscular activation pattern during voice production has been shown [23], and key muscles involved in voice production have been identified, including trunk extensors, cervical extensors, sternocleidomastoid, diaphragm, and intercostal muscles. The electromyographic (EMG) activity pattern of these muscles reflects the motor control exerted by the brain to enable stability; this pattern can be altered following central nervous system lesions, as was shown in individuals with spinal cord injuries [24]. Such defective muscle patterns will subsequently have a deleterious effect on respiratory and phonatory capacities, which are at the core of voice production.

Therefore, there is a need to investigate whether postural repositioning can improve MPD and, if so, by which mechanisms. In the current pilot study, we hypothesized that individuals with acquired dysarthria exhibit reduced MPD, as well as reduced respiratory capacities and altered EMG patterns in the trunk and neck muscles during voice production, compared to those in individuals without dysarthria. We further hypothesized that a short transdisciplinary seated postural repositioning intervention would immediately lead to enhanced MPD in participants with dysarthria (PWD) *via* improvements in respiratory capacities and the muscular activation of trunk muscles.

To verify these hypotheses, the present pilot study aimed (1) to assess the MPD in a prolonged/a/task at a conversational (1 m) and louder (6 m) voice level in PWDs before and after postural repositioning and in control participants in an upright sitting position; (2) to identify the mechanisms enabling an increase in MPD by assessing respiratory capacities in PWDs before and after the intervention and in control participants in an upright sitting position using manometry and thoracic expansion measurements, and by examining the muscular activation pattern in PWDs before and after the intervention and in control participants using EMG recordings of the neck and trunk muscles; and (3) to determine whether the PWDs can perceive a change in their performance by assessing the perceived level of effort required to perform the MPD tasks and satisfaction with their performance using clinical scales before and after postural repositioning.

Materials and methods

Study design and setting

A pre-post interventional study design was implemented. Quantitative and qualitative data were collected in a quiet laboratory room at a rehabilitation institute, in a single experimental session for both control participants (who did not have dysarthria) and PWDs. Quantitative data comprised the MPD, timed manometry, thoracic expansion, and EMG activation pattern of muscles located at the cervical and lower thoracic levels (see the **Tasks and outcome measures** section below). Qualitative data consisted of the perceived effort and satisfaction with performance, collected using scales that are in the process of being validated [15,25]. Both quantitative and qualitative measurements were obtained from dysarthric individuals before and after the intervention. Data was collected by the same three clinicians (SLP, physical and occupational therapist) for both the PWD and control participants. All experimental sessions were recorded using a video camera (20× optical zoom; Canon HD VIXIA HF R20). The experimental protocol was approved by the local ethics research board of Centre for Interdisciplinary Research in Rehabilitation (CRIR) and was in accordance with the principles outlined in the Declaration of Helsinki.

Each participant completed a single experimental session that lasted for 2 h, including equipment placement, postural repositioning, and procedural tasks. PWDs were assessed under two different conditions – namely, in the usual seated posture (USP) and corrected seated posture (CSP). The USP (Figure 1(a,c,e)) was defined as the posture naturally adopted by the participants upon arriving at the office, while talking to a therapist, without adjustments. No instructions regarding the participants' posture were provided at this stage in order to simulate what really happens in clinic when a patient arrives to the SLP's office; for example, patients often modify their posture by propelling themselves in a wheelchair to improve their comfort level. The CSP (Figure 1(b,d,f)) was achieved following a 10-min repositioning intervention, which was always implemented by the same two experienced physical and occupational therapists. Tasks were always assessed first in the USP and then in the CSP, ensuring that the PWDs were truly in their naturally adopted posture (i.e., as they independently presented to the laboratory in their manual wheelchair or naturally walked in and sat on an armchair).

The posture of control participants was assessed while they were comfortably seated on a regular chair. They were verbally instructed to have feet flat, symmetrical weight bearing, and symmetrical alignment of the head and trunk, resulting in self-repositioning to achieve an upright sitting position.

Control participants in an upright sitting position and PWDs in each posture (USP, CSP), were asked to perform the following tasks: (1) thoracic expansion; (2) respiratory support (manometer); and (3) MPD at normal conversational loudness (directed toward an individual standing at 1 m away from the participant) and at voice projection loudness (directed toward an individual standing at 6 m away from the participant). Each task is described in detail in the **Tasks and outcome measures** section below.

Participants

Individuals aged 18–65 years who had sustained a first episode of stroke, traumatic brain injury, or cerebral anoxia were recruited as

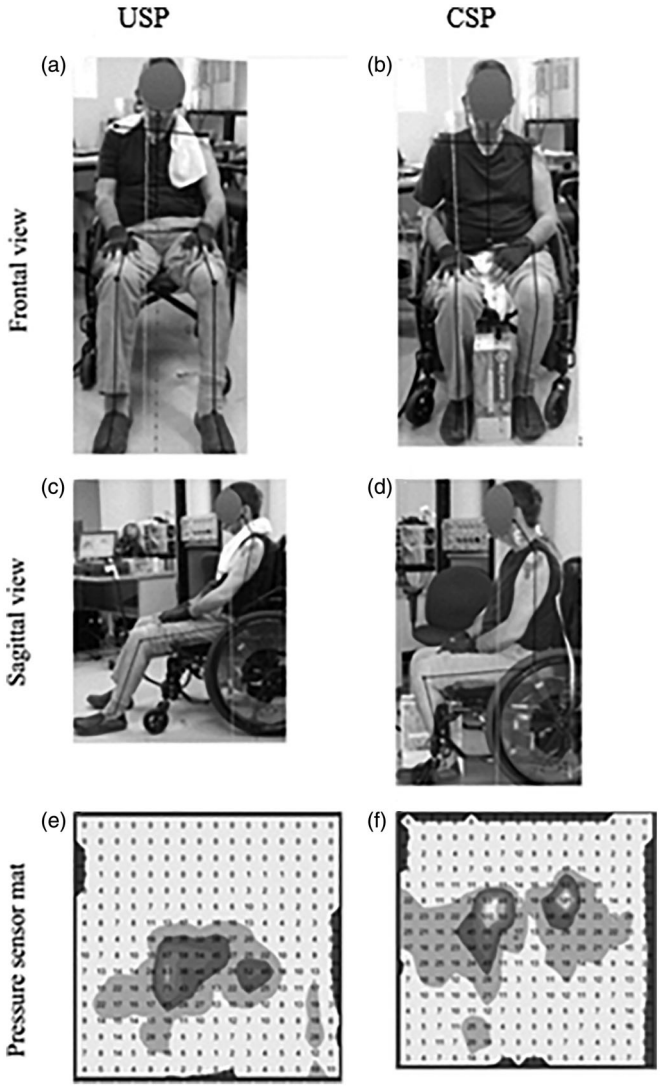


Figure 1. Methodological Set-up.

study participants. All PWDs were approached by a clinician who was working with the rehabilitation institute's neurology program but had no ties with the research team. PWDs were included if they (1) were diagnosed with acquired dysarthria by a speech and language pathologist; (2) had impaired postural control following a neurological injury; (3) were approaching the end of intensive rehabilitation (PWD #3) or had finished intensive rehabilitation and (4) had expressed a desire to participate in research. PWDs were excluded if they had any cognitive impairment that could prevent them from understanding directives or from expressing their opinion about their posture (comfortable, uncomfortable, etc.). A neuropsychologist clinically assessed the cognitive function of PWDs.

Healthy individuals' sex and age-matched (± 5 years) to the PWDs were recruited *via* posters at our rehabilitation institute. All participants received oral and written information regarding the procedures and purpose of the study, and subsequently provided written informed consent for study participation.

Tasks and outcome measures

Maximum phonation duration tasks

Maximum phonation duration (MPD) was assessed during a prolonged/a/task. The participants were french-speaking and were instructed as follows: "*Say 'ah' for as long and steadily as you can until you run out of air and in a voice loud enough to be heard by an experimenter standing at a 1-m/6-m distance from you.*" The 'ah' corresponded to the french 'ah' sound. Intentionally, no instructions regarding inspiration were provided prior to the task in order to examine what the participants would naturally do. The 6 m task was introduced to simulate a loud voice, as an adaptation of the LSVT therapy task, and corresponding to the reality of patients who have to talk louder if they want to pick up the attention of a caregiver passing in the corridor of their room. A voice recording was obtained using a cardioid condenser headset microphone (Audio-Technica ATM73a Artist Series; https://www.audio-technica.com/fr-ca/microphones/wired/line-series/artist-series/atm73ac), without a pad and with an 80-Hz high-pass filter that attenuated the bass to reduce reverberation, ambient noise, and sensitivity to voice "pops." The headset microphone was placed at a distance of 5 cm from the labial center and 2.5 cm from the labial commissure.

Analysis of quantitative variables

For analysis, the headset was connected to a computer installed with Praat software (downloaded from www.praat.org), with mono-recording conducted at a sampling rate of 22,050 Hz and a quantization resolution of 16 bits in the Microsoft WAV format. For better analysis, the entry volume of the system was calibrated in order to have the least waveform saturation possible in the Praat software, with the participants being instructed to utter a short/a/. Furthermore, for synchronized EMG and voice analysis, the voice was recorded along with the muscle signals using Spike software (Cambridge Electronic Device Ltd., Cambridge, England, UK).

Respiratory capacity tasks

Chest expansion. Participants were instructed to perform a deep inspiration ("as deep as possible") and to subsequently breathe out as much as possible. The participants were instructed as follows: "*Breathe in/out maximally and make yourself as big/small as possible.*" The trunk circumference at the level of the xyphoid process [26] was measured using a tape measure when the participants achieved maximal inspiration and maximal expiration. The difference in circumference between maximal inspiration and maximal expiration was subsequently calculated. These tasks were conducted with the PWDs in both USP and CSP and with the control participants in an upright sitting position.

Timed prolonged expiration (manometry). In 1982, Hixon et al. [27] proposed a noninvasive method using a water manometer with a 10-cm column to determine an individual's ability to generate respiratory driving subglottal pressure deemed sufficient for speech, and this method is still largely recommended clinically [1,10]. The participants were instructed as follows: "*Blow gently into the straw to make bubbles on the surface of the water for the longest time that you can.*" If a participant was not able to seal his mouth and nose, the therapists provided manual aid. As for MPD tasks, no instructions regarding inspiration were provided prior to the task. If the participants asked if they had to breathe in before performing the task, the answer was as follows: "*Do as you feel to adjust to the task.*" This task was filmed and timed, and the second trial was recorded. This task was conducted with the PWDs in both USP and CSP, and with control participants in an upright sitting position.

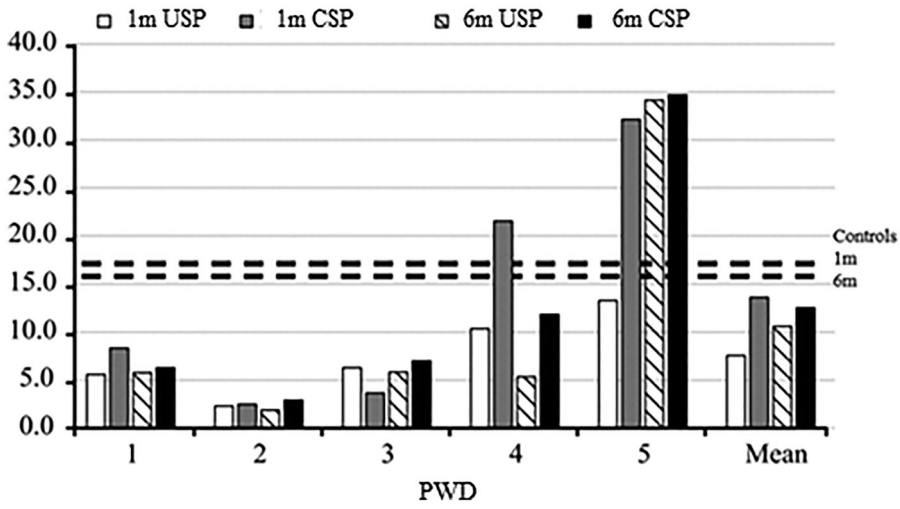


Figure 2. Effect of PWD's repositioning on prolonged/a/at 1 m and 6 m compare to control participants mean value in upright sitting position ($M = 16{,}9$ s at 1 m and 16,1 s at 6 m).

EMG activation pattern

Bilateral EMG activity during the MPD tasks was recorded using surface electrodes placed over muscles located at the cervical level (namely, the sternocleidomastoid and the erector spinae at the C4–C7 levels). We also recorded activity from the lower thoracic muscles; the electrodes were placed over the 8th intercostal level muscles (principally recording the diaphragm, as described by Demoule et al. [28], and the lower intercostal muscles) and the erector spinae at the T8 level. As the EMG pattern was similar between the sternocleidomastoid and erector spinae at the C4–C7 levels, only the EMG pattern of the sternocleidomastoid is described in the Results section. Additionally, as the EMG activity was similar between the lower intercostal muscles and erector spinae at the T8 level, only the EMG activity of the lower intercostal muscles is described in detail. EMG signals were acquired at 2000 Hz using Spike software, and were filtered (10–1000 Hz), amplified (1000×), and recorded on a computer for visual inspection and offline analysis.

Participants' perceived capacity and effort scales

Client satisfaction is recognized to be a part of evidence-based practice in medicine [29] and is highly recommended to be considered in therapy [30]. Thus, following the completion of MPD tasks, participants were requested to grade their perceived level of performance and effort in each posture (USP, CSP) using the Neuro-Environmental Rehabilitation twenty first Century (NER-21) scales [25]. In accordance with the scale guidelines, the participants were instructed to judge their MPD task performance on the performance scale and to subsequently indicate the effort required to speak on the effort scale under the 2 experimental postures (Figure 2). In this study, the dual-parameter NER-21 scales was preferred to the modified Borg scale, as it measures both effort and satisfaction with performance on a similar scale format. These scales are currently being validated in the stroke population36.

Intervention

A single session of postural repositioning, based on the current version of the Bobath [15,17,31–33] concept used in the clinic, was applied to PWDs. The Bobath concept is currently defined as a problem-solving approach employed in the assessment and treatment of individuals with function, movement, or postural control disturbances caused by a central nervous system lesion. This concept incorporates principles of neuroplasticity and motor learning and provides a way of observing, analyzing, and interpreting task performance, as well as facilitation techniques and techniques to manage compensatory motor behaviors, addressing movement dysfunctions [15,16,31,32]. This intervention has been shown to be effective in improving postural stability behaviors [32,34–36].

The 10-min transdisciplinary intervention aimed to (1) facilitate and activate axial extension, which was accomplished by having participants briefly stand up prior to having either the physical or occupational therapist sit them down appropriately in the wheelchair (or an armchair for the 1 ambulatory PWD), making sure the buttocks touched the backrest and the thighs were maximally supported by the seat; (2) actively mobilize the trunk, cervical spine, and pelvic and shoulder girdles; and (3) adjust the seated position, as needed, with supports to ensure CSP maintenance throughout the experiment. Cushion, balls, boxes, or rolls were used to stabilize the final seated position. The CSP maximized the axial alignment and symmetry, and is realistically reproducible in clinical settings; furthermore, each specific repositioning technique can be taught to an SLP prior to a speech therapy session. To confirm symmetry in the transverse plane during sitting, a pressure sensor map was used, which enabled the visualization of the main points of support (ischium) (Figure 1(e,f)). The pressure map (FSA or BodiTrak pressure mapping system) was installed on the seat cushion of the participant's wheelchair or chair to measure the weight distribution during sitting. The center-of-pressure excursion could subsequently be recorded and viewed in real-time (at an acquisition frequency of 50 Hz). This pressure map was also used to guide a more symmetrical base of support when adjusting to the corrected posture. Furthermore, the plumb line was used to maximize symmetry in the frontal and sagittal planes.

The final position achieved after this intervention was considered as the CSP for each PWD. This final position was not necessarily the ideal posture because of the severity of neuromuscular deficits in 4 participants with moderate and severe dysarthria. Nonetheless, the physical and occupational therapists aimed to get the participant's feet symmetrically placed on the floor, their heels in contact with the support surface, and their knees flexed at $>90°$, with the iliac crests and weight-bearing approaching symmetry and with axial alignment of the pelvis, sternum, and

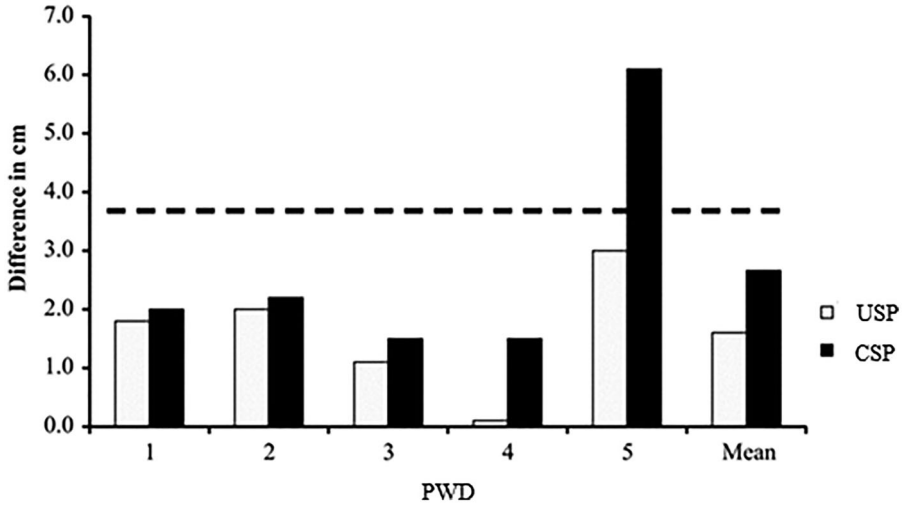


Figure 3. PWD's thoracic expansion at USP and CSP, compared to control participants mean value in upright sitting position ($M = 3{,}8$ s).

chin in the frontal plane, and that of the iliac crest, shoulders, and head in the sagittal plane. Once the CSP was attained, the SLP evaluated the capacity of the PWDs to produce an audible prolonged/a/by assessing the voice subjectively. Agreement on the optimal CSP and/a/production was reached between the therapist's team and the participants. Throughout testing, changes in the initial corrected posture were minimized by verbal cueing or light physical assistance between tasks, as necessary. Furthermore, if a change in the CSP was noted during experimentation, the physiotherapist and occupational therapist corrected the PWD's position.

Analysis of quantitative variables

MPD

The MPD was measured using Praat software (Figure 3(a,b)). The approximate start of vowel production was selected and enlarged; the first waveform production, which indicated the start of vowel production, was then selected as the beginning of vowel/a/production. The same analysis was conducted at the end of the production. In dysarthric speech, the waveform is not always periodic; hence, careful listening of the recordings aided in more precisely determining when the vowel production started and ended.

Respiratory capacity

Differences in thoracic expansion and manometric results were compared between control participants in an upright sitting position and PWDs, and between the USP and CSP in PWDs. For manometry, the duration of expiration was calculated both online, using a stopwatch, and offline, using video recordings. Indeed, the assessment of the sound produced by manometry (extracted from the video and transferred to Praat software) enabled more precise time calibration. An exact time calculation was possible by converting the video recording (MOV) of the experimentation into a WAV file using the following command in the Terminal on a Mac computer:/ffmpeg -i input.MOV output.wav (https://ffmpeg.org).

EMG activity pattern

Full-wave rectified EMG activity was filtered with a second-order Butterworth bandpass filter (75–500 Hz), and the following measurements were obtained: (1) latency between the onset of the first EMG burst and the onset of voice production, which was calculated as a measure of preparatory activity; (2) duration of the second phase, which was calculated as the percentage of the duration of voice production when EMG activity could not be observed in any of the recorded muscles; and (3) latency between the onset of the terminal EMG burst and the end of voice production. These three measurements were compared between control participants in the upright sitting position and PWDs at 1 m and 6 m, and between the USP and CSP in PWDs at 1 m and 6 m.

Statistical analysis

As this was a pilot study with a small number of participants (a grand total of 10, divided into two groups), descriptive statistics were used (mean ± standard deviation or mean ± standard error of the mean for EMG measures). Only the effect size (Cohen's *d*) and the lower (CI low) and upper (CI up) boundaries of the confidence intervals were calculated for respiratory and voice task variables. All analyses were performed using SPSS for Windows version 20.0 (IBM Corp., Armonk, NY).

Results

Participants

Five participants with acquired dysarthria after stroke ($N = 4$) or traumatic brain injury ($N = 1$) were compared to five age- and sex-matched control participants (1 woman) aged 45–62 years (mean, 54 ± 7 years). None of the PWDs had aphasia or cognitive problems that could affect participation in the experiment (determined by the clinical judgement of referring SLPs who were not part of the research team and assessed by a neuropsychologist). Table 1 summaries the comorbidities of the recruited participants, as well as their medication, state of dysarthria, and ongoing or past physical, occupational, and speech therapies. Dysarthria in the participants was classified into severe ($N = 2$), moderate ($N = 2$), and mild intelligibility impairment ($N = 1$), with scores ranging from 2 to 8 on the 10-point Intelligibility Rating Scale for Motor Speech Disorders (MSD) [1], which is a quantitative estimation scale for intelligibility in adult dysarthric speakers [1] that considers variables such as speaking environment, message complexity, and predictability.

All control participants were full-time staff at the rehabilitation institute (2 caregivers, 1 administrator, 1 neuropsychologist, and 1 physiotherapist), who were never diagnosed with dysarthria or

Table 1. PWD details.

Identifier	Age	Time post event (y, m)	Type of Injury (medical chart)	Type of dysarthria / Dysarthia caracteristics[a]	Intelligibility rating Scale for MSD1[b]		Locomotion / Physical status	Previous /actual SLT[c] (w,m,y)
PWD1	61	2, 1	Midbrain hemorragic stroke	Mixed Spastic/ and ataxic	2	Severe	Manual wheelchair, cannot walk / right ataxic and left spastic hemiplegia.	6m intensive / Once every 3w
PWD2	53	6, 10	Severe TBI	Spastic	2	Severe	Manual wheelchair cannot walk / double spastic hemiplegia	1y intensive / once a month
PWD3	50	0, 4	Hemor. Cerebellar and 4th ventricular Stroke	Mixed Ataxic/ flaccid Right flaccid facial paralysis	5	Moderate	Manual wheelchair, cannot walk / double ataxic hemiplegia	3m intensive / waiting for outpatient treatments
PWD4	61	6, 3	Lithium intoxication and severe cerebellum syndrome	Ataxic	6	Moderate	Manual wheelchair, cannot walk / Severe bilateral ataxia	2 periods of 3 m and 2 m intensive tx. 8 m as outpatient / Once a month for maintaining and adapt to everyday living
PWD5	45	1, 7	Anoxia post heart attack	Ataxic	8	Mild	Walking and active no technical support (several km/day)	2m. intensive and 2 m outpatient / None

[a]Type of dysarthria as described in Duffy, 2013 [1].
[b]Intelligibility rating scale for motor speech disorders (Duffy, 2013 [1]) between 10 (normal) and 1 (severe).
[c]Speech and language treatment.

any other voice impairment and had no comorbidities. Specifically, none of the control participants had breathing deficits (e.g., asthma, chronic obstructive pulmonary disease); pathologies in the spinal cord, spinal column, or thoracic cage that could prevent them from freely moving their trunk; or neurological or cardiac problems.

Maximum phonation duration (MPD)

At 1 m, control participants in an upright sitting position could utter/a/longer than PWDs in the USP (16.9 ± 7.9 s vs 7.6 ± 4.3 s; Cohen's $d = 1.47$, CI low = 0.07, CI up = 2.87). PWDs could utter/a/longer in the CSP than in the USP (with an increase of 80.3%, to 13.6 ± 12.8 s; Cohen's $d = 0.64$, CI low=-0.63, CI up = 1.91), except for one participant with moderate dysarthria (PWD #3) who had a shorter MPD. Interestingly, the MPD in the CSP in PWDs #4 and #5 surpassed the mean MPD of the control participants (Figure 2).

At 6 m, control participants in an upright sitting position could utter/a/longer than four of the PWDs in the USP (16.1 ± 9.4 s vs 10.6 ± 13.3 s; Cohen's $d = 0.48$, CI low=-0.77, CI up = 1.74). The MPD in one participant with mild dysarthria (PWD #5) was greater than the mean MPD in control participants (Figure 2). All PWDs could utter/a/longer in the CSP than in the USP; nevertheless, the effect size was small (10.6 ± 13.3 s in the USP vs 12.5 ± 12.8 s in the CSP; Cohen's $d = 0.14$, CI low=-1.9, CI up = 1.39).

A comparison between the/a/–1-m and/a/–6-m tasks indicated that control participants in the CSP uttered/a/longer at 1 m (16.9 ± 7.9 s) than at 6 m (16.1 ± 9.4 s). Similarly, irrespective of whether participants with severe or moderate dysarthria were in the USP or CSP, the mean MPD was always greater in the/a/–1-m task (6.1 ± 3.3 s in the USP and 9.0 ± 8.7 s in the CSP) than in the/a/–6-m task (4.7 ± 1.9 s in the USP and 7 ± 3.7 s in the CSP). Only the participant with mild dysarthria exhibited greater MPD in the/a/–6-m task (34.1 s in the USP and 34.7 s in the CSP) than in the/a/–1-m task (13.3 s in the USP and 32.1 s in the CSP). MPD data of the PWDs are provided in detail in Table 2 for all tasks/conditions.

Respiratory capacity

Thoracic expansion

In the USP, PWDs showed decreased thoracic expansion compared to that in the control participants in an upright sitting position (mean, 1.6 ± 1.1 cm vs 3.8 ± 2.6 cm; Cohen's $d = 1.97$, CI low= −0.22, CI up = 2.44). Analysis of each participant revealed that none of the PWDs had thoracic expansion values similar to the average value of the control participants (dotted line in Figure 3). Following postural repositioning, thoracic expansion values increased in all 5 PWDs (2.7 ± 1.9 cm in the CSP vs 1.6 ± 1.1 cm in the USP; Cohen's $d = 0.67$, CI low= −0.6, CI up = 1.95). The participants with mild dysarthria had a thoracic expansion value above the mean value of the control participants and showed the greatest improvement following postural repositioning (Figure 3). Interestingly, PWDs #3 (0.4 cm) and #4 (1.4 cm) (moderate dysarthria in both), as well as PWD #5 (3.1 cm) (mild dysarthria) exhibited greater improvement in thoracic expansion than did PWDs #1 (0.2 cm) and #2 (0.2 cm) (severe dysarthria in both).

Manometry

In the USP, PWDs showed a decreased duration of expiration compared to that in the control participants in an upright sitting position (mean, 17.1 ± 15.5 s vs 25.52 ± 5.3 s; Cohen's $d = 0.73$, CI low= −0.55, CI up = 2). More specifically, four of the PWDs exhibited a decreased duration of expiration compared to that in the control participants (10.4 ± 4.9 s vs 25.52 ± 5.3 s; Figure 5). In PWD #5 (mild dysarthria), the duration of expiration was 43.7 s, which was well above that in control participants.

Following postural repositioning, PWDs showed an increase in the mean duration of expiration (Figure 4); nevertheless, the effect size was very small (17.1 ± 15.5 s in the USP vs 18.16 ± 11.96 s in

the CSP; Cohen's $d = 0.08$, CI low=-1.16, CI up = 1.32). More specifically, the duration of expiration increased by 30.7% in the 4 participants with moderate or severe dysarthria (10.4 ± 4.9 s vs 13.6 ± 7.4 s), but decreased in the participant with mild dysarthria (43.7 s vs 36.3 s).

Triphasic and cervicothoracic EMG activation patterns

Control participants. Among control participants, a triphasic EMG activation pattern was observed in the recorded muscles during both prolonged/a/–1-m and/a/–6-m tasks (Figure 5(a)). Notably, during the/a/–1-m task, the *first phase* consisted of a burst of EMG activity immediately preceding the onset of voice production, ending with a sharp offset at the start of voice production (mean EMG onset of 1897 ± 522 ms and 1731 ± 512 ms prior to voice production in the right and left sternocleidomastoid, respectively; Supplementary Table 3a). Furthermore, EMG activity prior to the onset of voice production could be observed in lower intercostal muscles of three participants; however, in two of these participants (#2 and #4), the latency was later at lower intercostal level than in cervical muscles (Supplementary Table 3a). To gain insight regarding the origin/nature of this initial burst, audio recordings were assessed during the preparatory burst of EMG activity. Indeed, a short inspiration preceding voice production was always heard simultaneously with the first burst. It is important to note that this occurred even though no breathing instructions were provided to the participants.

In the *second phase*, once voice production started, EMG activity was greatly reduced or was absent during the first part of voice production (mean duration of voice production without EMG activation: 38 ± 12%; Supplementary Table 4a).

In the *third phase*, a terminal EMG burst was observed mainly at the lower intercostal level, which started from the middle part of voice production and increased in amplitude, reaching the maximum amplitude at the very end of the task (Figure 5(a); measures are presented in detail in Supplementary Table 5a). This triphasic EMG pattern was observed during both/a/–1-m (Supplementary Tables 3a–5a) and/a/–6-m MPD tasks (Supplementary Tables 3d–5d).

PWDs in the USP. In the participants with moderate and mild dysarthria, EMG activity preceded the voice production, in a similar pattern as was observed in the control participants. However, the delay between the EMG activity onset and the voice onset was shorter in PWDs for all evaluated muscles at 1 m (Cohen's $d = 0.6$–1.3) and 6 m (Cohen's $d = 1.1$–1.5). Furthermore, a short inspiration preceding voice production was not always heard in the audio recordings. More specifically, a triphasic EMG pattern was not observed in the two participants with severe dysarthria (see PWDs #1 and #2 in Supplementary Table 3b), with muscle activation throughout MPD production (Supplementary Table 4b). In the two participants with moderate dysarthria and one participant with mild dysarthria, a triphasic EMG pattern could be determined during the/a/–1-m task (see PWD #3–5 in Supplementary Tables 3b–5b). However, during the/a/–6-m task (Supplementary Table 4e), none of the PWDs showed a triphasic EMG pattern, as the muscles were activated throughout voice production.

PWDs in the CSP. Compared to that in the USP, postural repositioning enabled an earlier onset of EMG activity prior to voice production during the/a/–1-m task at the lower intercostal level (Cohen's $d = 0.4$–0.5), but not in the sternocleidomastoid (Cohen's $d = 0.9$–1.7). More specifically, postural repositioning did not lead to the emergence of a triphasic EMG pattern in the two participants with severe dysarthria. The CSP had mixed effects in the two participants with moderate dysarthria and one participant with mild dysarthria. Only PWD #5 (mild dysarthria) showed a triphasic EMG pattern during the/a/–1-m task, whereas all three of these participants exhibited a triphasic pattern in the USP. Following the repositioning, the onset of EMG activity preceding voice production during the/a/–1-m task was decreased in the majority of muscles; additionally, the onset of EMG activity preceding voice production during the/a/–1-m task was smaller in the CSP than in in the USP (compare Supplementary Table 3b vs. Table 3c). Nonetheless, during the/a/–6-m task, none of the participants exhibited the triphasic pattern observed in the USP,

Table 2. Maximum phonation duration (s) in PWDs during the/a/-1m and 6 m task.

	1m USP	1m CSP	6m USP	6m CSP
PWD1	5,6	8,4	5,8	6,3
PWD2	2,3	2,5	1,9	2,9
PWD3	6,3	3,7	5,8	7
PWD4	10,4	21,5	5,4	11,8
PWD5	13,3	32,1	34,1	34,7

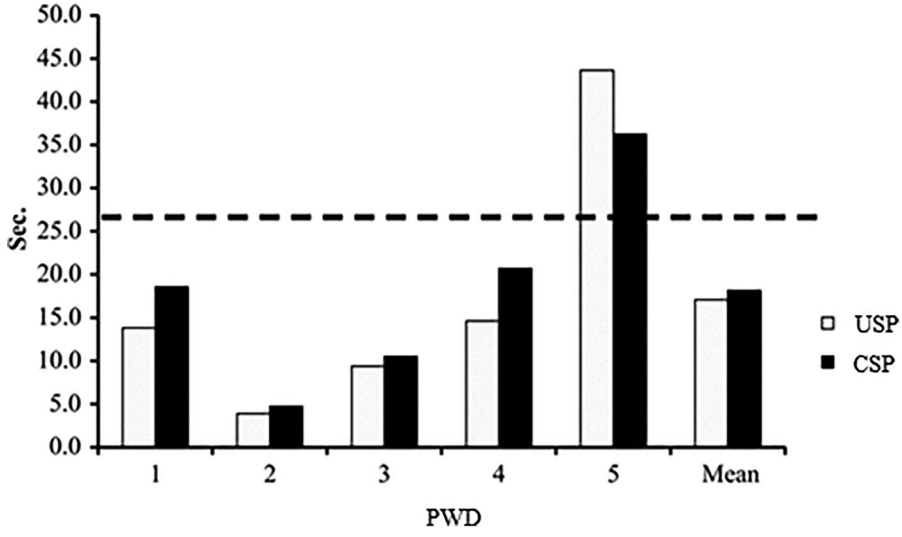


Figure 4. PWD's manometry at USP and CSP, compare to control participants mean value in upright sitting position ($M = 25{,}52$ s).

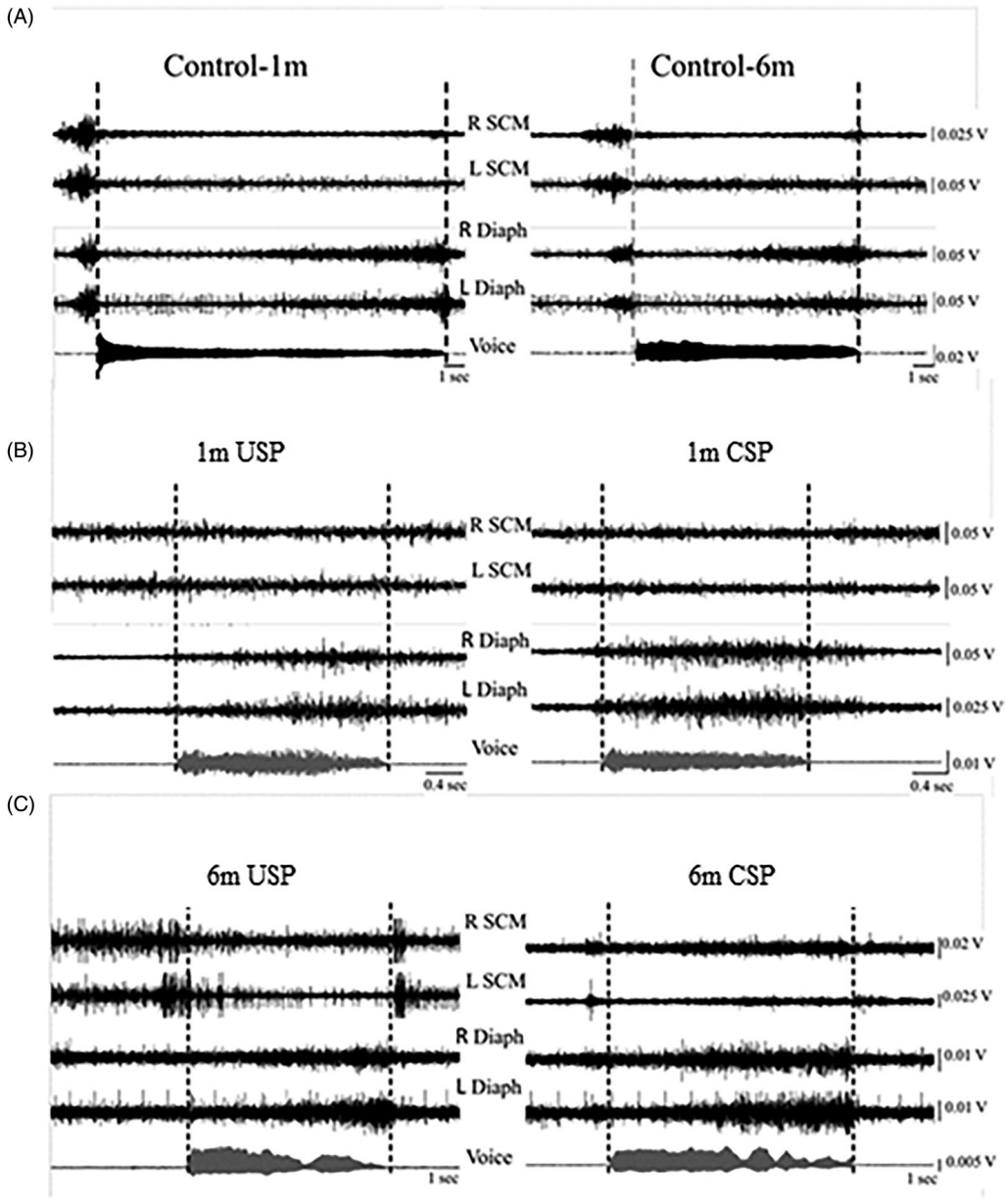


Figure 5. EMG pattern of EMG activity during prolonged voice production. (a) EMG activity pattern of a control participants at 1 and 6 m. EMG activity pattern of two participants with dysarthria; (b) Severe (PWD2) at 1 m; (c) Moderate (PWD3) at 6 m BEFORE and AFTER repositioning.

whereas the participant with mild dysarthria recovered the triphasic EMG pattern after postural repositioning.

Perceived effort and satisfaction

On the NER-21 "perception of effort" scale (Figure 6(a)), the control participants indicated that the performance of the/a/–6-m and/a/–1-m MPD tasks required very little effort (mean of 1/10; dotted line in Figure 6(a)). In contrast, the PWDs perceived that considerable effort was required to perform these tasks (mean of 6.8/10; Figure 6(a); Cohen's $d = 6.29$, CI low = 3.27, CI up = 9.3). However, after postural repositioning, the PWDs reported that the tasks required less effort than that before the intervention (mean = 4.6; Cohen's $d = 1.97$, CI low = 0.46, CI up = 3.47).

On the NER-21 "satisfaction with performance" scale (Figure 6(b)), the control participants indicated that they were very satisfied with their performance, unlike the PWDs in the UPS (9/10 vs 4.2/10; Cohen's $d = 3.13$, CI low = 1.28, CI up = 4.98). However, the PWDs reported that they were more satisfied with their performance after postural repositioning than before the intervention (6.3/10 vs 4.2/10; Cohen's $d = 1.34$, CI low = 0.03, CI high = 2.71).

Discussion

The primary objective of this pilot study was to determine whether a short-time transdisciplinary postural repositioning intervention, optimizing axial alignment and symmetry, would immediately lead to an improvement in MPD among PWDs. We found that the MPD during both 1-m and 6-m tasks was increased by the intervention in PWDs.

The secondary objective was to identify the mechanisms enabling an increase in phonation duration by assessing respiratory capacities and EMG activity pattern in muscles located at the cervical and lower intercostal levels. We found that all PWDs

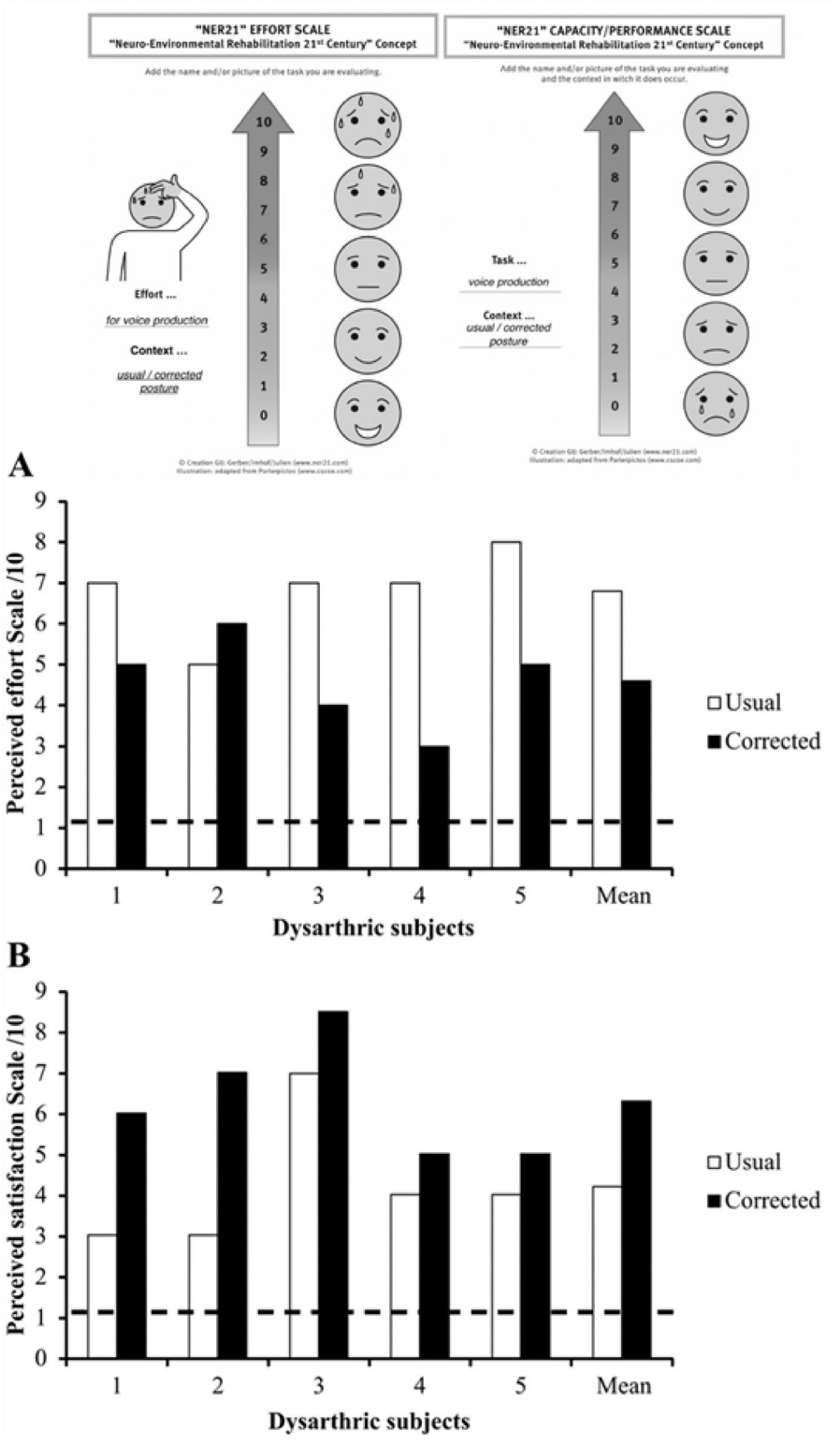


Figure 6. NER21 scales. (A) PWD's perceived effort scale between USP and CSP for voice task compare to control participants mean value in upright sitting position ($M = 1$). (B) PWD's perceived capacity satisfaction scale between USP and CSP for voice task compare to control participants mean value in upright sitting position ($M = 9$).

exhibited better thoracic expansion, and that, with the exception of the participant with mild dysarthria, all PWDs had better manometric results in the CSP than in the USP. These findings suggest that postural repositioning increased respiratory capacities, which directly contributes to the MPD. However, the postural repositioning did not lead to the emergence of a triphasic EMG pattern in PWDs who did not initially exhibit the triphasic pattern in the USP during the 6-m task, with the exception of the participant with mild dysarthria. Thus, changes in the EMG activity pattern likely did not contribute to improved MPD task performance in this pilot study.

The third objective was to determine whether the PWDs could perceive a change in their performance. After postural

repositioning, the PWDs perceived that the performance of the MPD tasks required less effort; additionally, they were more satisfied with their performance after postural repositioning.

Overall, this study suggests that a short 10-min intervention can immediately enable better breathing support and less effort during MPD tasks among PWDs. Therapies provided by the SLP for dysarthria can be optimized by performing short postural repositioning prior to speech therapy. Furthermore, these data support the collaboration of physical and occupational therapists, SLPs, and the PWDs themselves to established common goals and verify that these goals can be attained [15,16].

Improvement in the MPD

The control participants were able to utter a prolonged/a/with a mean duration of 16.9 s at 1 m and 16.1 s at 6 m, which is in accordance with the results of previous studies that reported 15 s as the median minimum in healthy control participants [1,10]. Although we did not find any data from the literature comparing the MPD between normal conversational and voice projection levels, we can infer here that a louder voice slightly influences the results, as the duration was shorter during the 6-m task than during the 1-m task. The participants with moderate or severe dysarthria tended to show similar results with respect to the production of a conversational voice versus a louder voice (mean voice duration, 6.1 s vs 4.7 s in the USP and 9 s vs 7 s in the CSP; Table 2). This could be explained by the subglottal pressure required to produce a loud voice, as compared to that for a normal voice. In fact, the production of a louder voice can increase the muscular tone in PWDs, which is often already too high in this population [15].

The corrected posture had a positive effect in all PWDs at both 1 m and 6 m (Figure 6). Only PWD #3 had a lower result at 1 m. The observed improvement in the MPD could be due to the better positioning of speech organs in dysarthric speakers. Indeed, a previous study involving healthy participants reported that speech depends on the head posture, which itself is dependent on the hyoid, vertebral column, and pelvis [19]. Other studies suggest that a neurological rehabilitation approach for physical therapy is effective in improving postural stability [32,34–36], and can also contribute to an improvement in breathing and speech production.

Improvement in respiratory capacities

In the current study, respiratory capacities were found to improve after postural repositioning and, therefore, contribute to an increased MPD. It was difficult to compare the values obtained for the control participants to those in the literature because thoracic expansion measurements are usually performed in the standing position but were performed during sitting in the current study. In the study conducted by Olsén et al. [26], the norms were 6.8 ± 1.9 cm for woman and 8.1 ± 2.5 cm for men in the standing position, which are greater than those for our control participants (i.e., mean, 3.8 cm; maximum, 6.1; minimum, 0.9). Nonetheless, in comparing the data from control participants and PWDs under the same condition, we observed that the performance level of all PWDs in the USP was below the performance level of the control participants, and that all PWDs benefited from repositioning when compared to themselves. The participant with mild dysarthria even performed at a level similar to the control participants. The participant with moderate dysarthria seemed benefit the most from repositioning with respect to thoracic expansion. Interestingly, the two participants with severe dysarthria showed very little thoracic expansion in both the USP and CSP. These three participants also had a shorter MPD, in all conditions tested. This may suggest that a lack of thoracic expansion may be a factor contributing to short/a/prolongation.

In terms of manometry, all PWDs benefited from postural repositioning, and the duration of manometry increased in all PWDs with the exception of the participant with mild dysarthria, whose average value was already over that of the control participants. As mentioned in the **Materials and Methods** section, it is important to note that the participant with mild dysarthria is the youngest participant (45 years old) and had relatively no physical incapacities. His overall physical condition was very good as he was walking several kilometers a day, which could explain the results. Hence, the four participants with moderate and severe dysarthria benefitted from postural repositioning, with a 30.7% mean improvement in the manometric results (10.4 s in the USP and 13.6 s in the CSP). According to Hixon et al. (1982), a duration of 5–10 s of respiratory subglottal pressure sufficient to produce functional speech is healthy [27]. In the present study, three PWDs could reach over 10 s in the USP and a fourth PWD could reach this duration in the CSP. In one participant with severe dysarthria, the duration of manometry was 3.9 s in the USP and reached 4.7 s in the CSP. According to Yorkston et al. [10], this 0.8-s difference (21.2% increase) almost reaches the 5 s minimum target for functional speech, and may be sufficient to have a positive effect on speech production.

EMG activation pattern in control participants

A triphasic EMG activation pattern was observed in control participants, which resembles that described by Watson et al. during breathing tasks in classical singers [23]. Indeed, in the *first phase*, the EMG burst occurred immediately before the onset of voice production during the MPD task, and seems to reflect a short inspiration in preparation for the MPD task, as supported by the audio recordings. This suggests that this EMG burst reflects the short inspiratory effort requirements of the tasks as perceived by the participants. In the *second phase,* no activity in any of the muscles was observed during voice production. This is probably due to the passivity of expiration, which is controlled by the gradual return of the diaphragm to its original position. In the *third phase,* when approaching the end of voice production, another EMG burst, which started with a small amplitude and gradually increased until the end of voice production, was observed. This likely reflects the participant's planification process to produce the sound for as long as possible. This EMG burst was especially observed at the lower intercostal level. As the diaphragm is an inspiratory muscle, other muscles, such as the internal intercostal and the abdominals may contribute to this progressive phase and aid, by expiration, to prolong voice production.

EMG activation in the PWDs

The triphasic pattern was different in PWDs, suggesting that the decreased MPD production ability observed in the participants with moderate or severe dysarthria is in part due to the inappropriate EMG activation of the trunk and neck muscles immediately prior to and during voice production. Indeed, the duration of the preparatory EMG burst prior to voice production was shorter or absent during both/a/–1-m and/a/–6-m tasks in PWDs. Moreover, in verbal recordings, a short inspiration preceding MPD production was rarely heard or observed in the Praat's graphics,

suggesting that PWDs did not "prepare" for the task. These results are interesting and echo findings of studies investigating anticipatory postural adjustments in individuals with lesions to the central nervous system. Indeed, a burst of EMG activity is observed in the muscles, ensuring stability prior to an arm or a leg movement in controls, but is absent in individuals with stroke [36,37]. In order to still perform the tasks, individuals with stroke use compensatory postural reactions, which activate muscles that are not normally used in accomplishing the task. In the current study, participants with severe dysarthria showed constant EMG activation during MPD production, suggesting that they are not taking advantage of the passive return of the diaphragm to its position in the first part of voice production, and instead are using compensatory strategies.

Following postural repositioning, the duration of the preparatory EMG burst preceding MPD production increased in the majority of muscles in PWDs. This most likely improved the preparation for the task and the performance of the task itself. However, postural repositioning did not lead to the emergence of the triphasic pattern observed in the PWD, as no period of silence occurred.

Participants with mild and moderate dysarthria showed a preparatory EMG burst prior to MPD production; nevertheless, the duration of the burst decreased following postural repositioning. This was unexpected and is the opposite of what was observed with severe dysarthria. However, as the participants with mild and moderate dysarthria exhibited improved performance in the CSP (longer duration of/a/), this result suggests that despite the decreased duration of the preparatory EMG burst, its efficacy might be increased. Direct recordings of other muscles (e.g., the abdominal muscles) and EMG amplitude quantification could provide insight regarding this finding.

Postural repositioning led to the emergence of a triphasic EMG pattern in one of the participants during the/a/–6-m task, suggesting that the CSP might be effective for participants with mild or moderate dysarthria. Overall, postural repositioning had a beneficial effect on the EMG activity pattern prior to and during MPD production (mainly during the/a/–1-m task). Nonetheless, its precise effect may depend on the severity of the neurophysiological impairment and incoordination of respiratory muscles.

Perceived capacity and effort scales

After postural repositioning, 4 out of 5 PWDs reported that the MPD task required less effort and all PWDs were more satisfied with their performance. These results are concordant with the MPD task results and suggest that PWDs are good judges of their own performances. This reinforces PWDs as good collaborators in therapy and should be included in the analysis of their own performances [5,14,15,25].

Limitations and biases

The current study was a pilot study. Future studies with larger sample sizes would yield greater statistical power and may further reduce the influence of inter-participant variability, which can potentially inhibit the detection of statistically significant changes among groups. Inter-participant variability due to factors such as the severity and type of dysarthria can also be reduced in future studies by classifying the participants according to these categories.

Furthermore, perceptual analyses (Duffy rating scale) can be subjective. As no examiner inter-agreement coefficient was performed this could bring a bias in the report of the dysarthria severity. Also, bias could have been introduced in the manometric testing as PwD#3 who had a flaccid component including a facial hemiparesis was not able to seal his mouth and nose. Therefore, the therapists provided manual aid.

Another possible bias is the seated position taken by control subjects. Indeed, the position of control subjects was reached following self-repositioning which could be variable among participants, however therapists also provided verbal assistance to have optimal axial and alignment symmetry, as mentioned in the Materials and methods, section study design and setting.

Clinical implication

With postural repositioning, the duration of expiration was prolonged and the MPD was increased in PWDs. However, the triphasic EMG pattern remained dissimilar to that observed in control participants. This suggests that although rapid postural repositioning is efficient in increasing the MPD in the short term and should constitute a basis for speech therapy to prime the participant for respiratory/phonatory tasks, it is not a therapy in and of itself. As mentioned above, even in the CSP, the PWDs were not in an ideal posture (e.g., pelvic tilt, thoracic kyphosis, forward head posture), suggesting that a 10-min session is not enough to fully address severe neuro-motor impairments. Nonetheless, a positioning performed by the SLP just prior to the therapeutic session would enable optimal conditions for voice therapy. Furthermore, when combined with a transdisciplinary approach and physical/occupational therapeutic treatments, such regular postural repositioning would contribute to better overall posture and motor control in PWDs in the longer term.

Furthermore, the EMG pattern analysis revealed that PWDs had a decreased duration of preparatory burst activity (phase 1), which corresponds to a short preparatory inspiration. Thus, therapists could explicitly instruct their patients to take a short inspiration -instead of a dep breath as often asked in therapy- prior to the performance of vocal tasks during therapy, as a possible strategy to enable the emergence of a triphasic pattern and, hence, to achieve better voice performance. Overall, the data from this pilot study indicate that maintaining the CSP for a short period prior to speech therapy could optimize the effects of speech therapy. These data echo recent findings that emphasize the importance of postural control in rehabilitation [36,37].

Future directions

Future projects should specifically target the motor control of PWDs in speech therapy by conducting repetitive sessions in which the participants are properly positioned and instructed to take a brief inspiration prior to the performance of any speech production task. This could facilitate an earlier onset of EMG activity and promote a triphasic EMG pattern, which underlies voice production in control participants. Additionally, the results obtained after only one session may be predictive of the PWDs' ability to benefit from transdisciplinary approaches that integrate postural and speech aspects. Furthermore, as the proposed therapeutic paradigm did not have the same effect in all participants (compare participants with severe vs moderate vs mild dysarthria), further analysis of the effects of postural repositioning should be performed in relation to the functional abilities of each PWD and the degree of severity.

After postural repositioning using neurological rehabilitation approaches, some PWDs may benefit more in terms of the MPD

at normal conversational loudness (1 m), whereas others may benefit more in terms of the MPD at voice projection loudness (6 m). This suggests that some dysarthric individuals might be better candidates for therapies such as *smooth therapy* [12], whereas others may be more suitable for louder therapies such as LSVT [11]. More studies on these aspects would be particularly interesting.

Conclusions

Postural repositioning has immediate beneficial effects on the respiratory and phonatory capacities of PWDs. The data from this study indicate that therapy could include enhancing the preparatory phase by appropriately positioning PWDs and by instructing them to take a short inspiration, which control participants spontaneously do. This approach is complementary to other current emerging approaches using smooth or loud therapy, depending on the PWD. Additionally, asking PWDs to actively participate in their own therapy and in the analysis of their own performances would add an important and central perspective to the attainment of therapeutic goals.

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References

[1] Duffy JR. Motor speech disorders: substrates, differential diagnosis, and management. 3rd ed. Toronto: Elsevier-Mosby Inc; 2013. p. 578.
[2] Flowers HL, Silver FL, Fang J, et al. The incidence, co-occurrence, and predictors of dysphagia, dysarthria, and aphasia after first-ever acute ischemic stroke. J Commun Disord. 2013;46(3):238–248.
[3] Murdoch BE, Theodoros DG. Traumatic brain injury: associated speech, language, and swallowing disorders. Australia: Singular Thomson Learning; 2001.
[4] Winstein CJ, Stein J, Arena R, et al. Guidelines for adult stroke rehabilitation and recovery: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2016;47(6):e98–e169.
[5] Walshe M. The psychosocial impact of acquired motor speech disorders. In: Lowit A, Kent RD, editors. Assessment of Motor Speech Disorders. San Diego (CA, USA): Plural Publishing; 2011.
[6] Finch E, Rumbach AF, Park S. Speech pathology management of non-progressive dysarthria: a systematic review of the literature. Disabil Rehabil. 2018;42(3):296–306.
[7] Mitchell C, Bowen A, Tyson S, et al. Interventions for dysarthria due to stroke and other adult-acquired, non-progressive brain injury. Cochrane Database Syst Rev. 2017;(1):CD002088.
[8] Netsell R, Daniel B. Dysarthria in adults: physiologic approach to rehabilitation. Arch Phys Med Rehabil. 1979;60(11):502–508.
[9] Ramig L. The role of phonation in speech intelligibility: a review and preliminary data from patients with Parkinson's disease. In: Kent R, editor. Intelligibility in speech disorders: theory, measurement, and management. Amsterdam: John Benjamin; 1992. p. 119–155.
[10] Yorkston KM, Beukelman DR, Strand EA, et al. Management of motor speech disorders in adult and children. 3rd ed. Austin (TX): Pro-Ed; 2010. p. 592.
[11] Sapir S, Spielman J, Ramig LO, et al. Effects of intensive voice treatment (the Lee Silverman Voice Treatment [LSVT]) on ataxic dysarthria: a case study. Am J Speech Lang Pathol. 2003;12(4):387–399.
[12] Stocks R, Dacakis G, Phyland D, et al. The effect of smooth speech on the speech production of an individual with ataxic dysarthria. Brain Inj. 2009;23(10):820–829.
[13] Park S, Theodoros D, Finch E, et al. Be clear: a new intensive speech treatment for adults with nonprogressive dysarthria. Am J Speech Lang Pathol. 2016;25(1):97–110.
[14] Mackenzie C, Paton G, Kelly S, et al. The living with dysarthria group: implementation and feasibility of a group intervention for people with dysarthria following stroke and family members. Int J Lang Commun Disord. 2012;47(6):709–724.
[15] Sackett DL, Strauss SE, Richardson WS, et al. Evidence-based medicine: how to practice and teach EBM. 2nd ed. Edinburgh: Churchill Livingstone; 2000.
[16] Hansen TS, Jakobsen D. A decision-algorithm defining the rehabilitation approach: 'facial oral tract therapy'. Disabil Rehabil. 2010;32(17):1447–1460.
[17] Gerber M. Approche thérapeutique neuro-environnementale après une lésion cérébrale. Paris: De Boeck/Solal; 2014. p. 354.
[18] Rammage LM, Morrison M, Nichol H. Management of the voice and its disorders. 2nd ed. Clifton Park: Delmar Cengage Learning; 2001.
[19] Staes FF, Jansen L, Vilette A, et al. Physical therapy as a means to optimize posture and voice parameters in student classical singers: a case report. J Voice. 2011;25(3):e91–e101.
[20] Lagier A, Vaugoyeau M, Ghio A, et al. Coordination between posture and phonation in vocal effort behavior. Folia Phoniatr Logop. 2010;62(4):195–202.
[21] Murdoch BE. Acquired speech and language disorders: a neuroanatomical and functional neurological approach. 2nd ed. United States: Wiley-Blackwell; 2009.
[22] Rimmer KP, Ford GT, Whitelaw WA. Interaction between postural and respiratory control of human intercostal muscles. J Appl Physiol. 1995;79(5):1556–1561.

[23] Watson AH, Williams C, James BV. Activity patterns in latissimus dorsi and sternocleidomastoid in classical singers. J Voice. 2012;26(3):e95–e105.
[24] Tamplin J, Brazzale DJ, Pretto JJ, et al. Assessment of breathing patterns and respiratory muscle recruitment during singing and speech in quadriplegia. Arch Phys Med Rehabil. 2011;92(2):250–256.
[25] Gerber M. Échelles motivationnelles NER21 pour les personnes en situation de handicap, leur entourage et les thérapeutes impliqué/es dans le processus de réadaptation. 3ème colloque québécois de la réadaptation physique. Montréal; 2018.
[26] Olsén MF, Lindstrand H, Broberg JL, et al. Measuring chest expansion; a study comparing two different instructions. Adv Physiother. 2011;13(3):128–132.
[27] Hixon TJ, Hawley JL, Wilson KJ. An around-the-house device for the clinical determination of respiratory driving pressure: a note on making simple even simpler. J Speech Hear Disord. 1982;47(4):413–415.
[28] Demoule A, Verin E, Locher C, et al. Validation of surface recordings of the diaphragm response to transcranial magnetic stimulation in humans. J Appl Physiol. 2003;94(2):453–461.
[29] Haynes RB. What kind of evidence is it that evidence-based medicine advocates want health care providers and consumers to pay attention to? BMC Health Serv Res. 2002;2:3.
[30] Brady MC, Clark AM, Dickson S, et al. Dysarthria following stroke: the patient's perspective on management and rehabilitation. Clin Rehabil. 2011;25(10):935–952.
[31] Graham JV, Eustace C, Brock K, et al. The Bobath concept in contemporary clinical practice. Top Stroke Rehabil. 2009;16(1):57–68.
[32] Davies PM. Step to follow: the comprehensive treatment of patients with hemiplegia. 2nd ed. Berlin, New York: Springer; 2000.
[33] Vaughan-Graham J, Cott C, Wright FV. The Bobath (NDT) concept in adult neurological rehabilitation: what is the state of the knowledge? a scoping review. Part I: conceptual perspectives. Disabil Rehabil. 2015;37(20):1793–1807.
[34] Kollen BJ, Lennon S, Lyons B, et al. The effectiveness of the Bobath concept in stroke rehabilitation: what is the evidence? Stroke. 2009;40(4):e89–e97.
[35] Paci M. Physiotherapy based on the Bobath concept for adults with post-stroke hemiplegia: a review of effectiveness studies. J Rehabil Med. 2003;35(1):2–7.
[36] Levin MF, Panturin E. Sensorimotor integration for functional recovery and the Bobath approach. Motor Control. 2011;15(2):285–301.
[37] Ryerson S, Byl NN, Brown DA, et al. Altered trunk position sense and its relation to balance functions in people post-stroke. J Neurol Phys Ther. 2008;32(1):14–20.