How cognitive loads modulate the postural control of older people with low back pain?

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Abstract

Background: PC is a strong risk factor for falling in older people, particularly in older individuals with low back pain (LBP). Cognitive involvement in postural control (PC) increases with age.However, most scholars have not considered different difficulty levels of cognitive loads when exploring the effects of cognition on PC in older patients with LBP. To investigate how different levels of cognitive loads modulate PC in older patients with LBP.

Methods: This was a cross-sectional study. Twenty older women with LBP were recruited into the LBP group, and 20 healthy older women without the history of LBP were recruited into the healthy control (HC) group. Balance parameters were computed to quantify PC. All participants underwent the static balance test (SBT), which required the participant to maintain stability during standing on a force platform with or without a concurrent a cognitive task. The SBT included three levels of difficulties of posture tasks (eyes-open vs. eyes-closed vs. and one-leg stance) and three cognitive tasks (without cognitive task vs. auditory stimulation calculator task vs. serial-7s arithmetic task).

Results: A repeated-measure analysis of variance (3 postural tasks × 3 congnitive tasks× 2 groups) testing the effects of the different congnitive task levels on the performance in different postural conditions.Older people with LBP had worse PC (as reflected by larger center of pressure (COP) parameters) than HCs regardless of postural or cognitive difficulties. Compared with the single task, the COP parameters of participants with LBP were larger during dual tasks, even though the difficulty level of the cognitive task was low. Larger COP parameters were shown only if the difficulty level of the cognitive task was high in HCs. Correlations between sway area/sway length and the number of falls were significant in dual tasks.

Conclusion: Our findings shed light on the how cognitive loads modulate PC for older people with LBP. Compared with HCs, cognitive loads showed more disturbing effects on PC in older people with LBP, which was associated with falling.

1. Background

It has been reported that around one-third of older people (age > 60 years) have a high risk of falling (falling at least once a year)[1]. Poor postural control (PC) is strongly associated with a high risk of falling for older adults[2]. Studies have shown that cognition can modulate PC[3] and that the modulation effect increases with aging[4]. In daily life, it is very common for postural tasks to be accompanied with cognitive tasks (e.g., making a telephone call while walking). In such situations, attentional resources must be divided to undertaken both tasks appropriately[5].

Studies have shown that decreased/divided attention is a high risk factor for falling in daily life for older people[6]. The reason is that older people show poor performance in maintaining motor patterns or PC in dual tasks, in which postural and cognitive tasks must be completed simultaneously. Brauer and colleagues[7] reported postural stability to be impaired among older participants with a history of falling as compared with that in healthy counterparts while undertaking a dual task (verbal reaction to an auditory-tone task). If one of the dual tasks needs a high level of arousal or increased attentional demand, sufficient cognitive resources may not be able to be allocated to carry out daily activities (e.g., undertaking functional activities and maintaining postural balance simultaneously), thereby leading to higher risk of falling. Huxhold and coworkers[8] showed that older people have enhanced postural stability in a dual task, of which the cognitive task is easy. However, postural stability is reduced in a dual task with a more demanding cognitive task. Their findings are in accordance with the "U-shaped" relationship between PC and cognitive demands, which suggests that high and low cognitive demands have different effects upon PC in dual-task conditions[5].

A prospective study showed that older people in the community with low back pain (LBP) had a significantly higher risk of falling than older people without pain, which was likely associated with impaired PC in the individuals with LBP[9]. Studies have demonstrated that older people with LBP may have impaired PC compared with healthy older adults[10–12]. However, adoption of only a single postural task is not sufficient to explain PC ability in daily lives, which requires completion of multiple tasks simultaneously. Some studies have shown that higher cognitive loads could reduce the PC of people with LBP in a dual-task paradigm. For instance, Etemadi et al.[13] found that a LBP group had worse PC and cognitive performance under a dual-task condition than that of a control group. Nevertheless, Salavati et al.[14] found that the PC of participants with LBP did not differentiate with that of a control group in the dual-task condition, but the conigitve performance of LBP group was impaired in the posutral task with higher difficulty. There may be two reasons for these inconsistent findings: (i) those studies did not take different difficulty levels of postural tasks and cognitive tasks into consideration; (ii) the sample population in those dual-task studies were young and middle-aged people with LBP. For older people, contradictory results in bipedal standing have been shown in participants with LBP compared with that in healthy controls (HCs)[15–16]. However, little is known about the modulation of cognitive loads to PC in older people with LBP.

Besides the role of age-associated changes in brain function on balance and mobility decline in the eldly people, it was reported that chronic LBP could lead to the cognitive decline[17–18], which may sequentially have an impact on PC. Thus, it is critical to investigate the interaction between LBP and cognitive declineon PC. Understanding this interaction could aid understanding of the mechanism underlying falling for older people with LBP. In the present study, we employed different levels of difficulties for postural tasks and cognitive tasks to explore how cognitive loads modulate the PC in older people with LBP assessed under single-task and dual-task conditions. We hypothesized that impaired PC performance would be observed in older people with LBP compared with that in healthy older people regardless of the difficulty of the postural task or cognitive task. It was also anticipated that cognitive performance was impaired when the the postural task was difficult.

2. Methods

2.1. Participants

Twenty patients with LBP (LBP group) and 20 HCs (control group) were recruited in local community. The study protocol was approved by the ethics committee of the First Affiliated Hospital of Sun Yat-sen University(grant number#2019469) in Guangzhou, China, in accordance with the Declaration of Helsinki and informed consent was obtained from individuals prior to participation. The inclusion criteria for the LBP group were: (i) age > 60 years; (ii)nonspecific LBP for ≥ 3 months in the previous year; (iii) the worst pain during the previous 3 months rated 3 to 10 (out of 10) on a visual analog scale (VAS); (iv) a Mini-Mental State Examination(MMSE) score > 24 (out of 30) and Montreal Cognitive Assessment (MoCA) score > 26 (out of 30). Patients with LBP were excluded if any of the following criteria were met: (i) a history of spinal or low-extremity surgery,traumatic event, endocrine/neuromuscular disease, spinaltumor, rheumatologic disease of the spine, arthritis or orthopedic disease, orthostatic hypotension, vision, vestibular-systemdisease or any other physical injury that might affect balance; (ii) use of psychoactive or antihypertensive drugs (antidepressants, antipsychotics, sedatives/hypnotics, antiepileptics, antiparkinsonian drugs); (iii) severe posture abnormalities.

2.2. Instruments and experimental design

2.2.1. Static balance test (SBT)

In the SBT, PC was measured by the center of pressure (COP) in two conditions: single task (involving only a postural task) and dual task (carrying out the postural task with a concurrent cognitive task) (Fig. 1).

2.2.1.1. Postural task

The postural task required a participant to stand barefoot on a force platform with his/her arms hanging by the side. This task could be divided into three conditions of different difficulty while standing on the force platform: (i) with eyes open; (ii) with eyes closed; (iii) taking a one-leg stance. COP displacements were recorded using TecnoBody™ (PK254P; TecnoBody, Rome, Italy). The COP parameters measured were sway length (mm), sway area (mm^2), anteroposterior (AP) velocity (mm/s) and mediolateral (ML) velocity (mm/s) computed by the TecnoBody system. Each condition was repeated thrice, with each lasting for 30 s. Three conditions were assigned randomly to participants. Before testing, participants were required to stand on the force platform to become familiar with the test environment, and to select the most suitable standing leg for testing.

2.2.1.2. Cognitive task

The cognitive task consisted of two subtasks of high difficulty and low difficulty. The subtask of low difficulty was an auditory arithmetic task (Task 1). In the latter, the participant was required to calculate 100 minus 7 by an auditory cue. Then, the participant needed to give a response after the auditory cue within 30 s. The other subtask with high difficulty was a “serial-7 s arithmetic task” (Task 2), similar to the task in the study by Swanenburg and colleagues[19]. In the serial-7 s arithmetic task, the participant was required to start with 100, then subtract 7 several times as soon as possible within 30 s. Each subtask was repeated thrice, with each lasting for 30 s. Two subtasks were assigned randomly to participants. The percentage accuracy in all cognitive tasks was used in subsequent data analyses.

Each participant also undertook two calculation tasks sitting in a chair: sitting with eyes-open or sitting with eyes-closed. The purpose of the calculation tasks in the sitting position was to ensure that each participant could complete the cognitive tasks. The cognitive performance in the sitting position was used in data analyses as the baseline of cognitive performance[20].

2.2.2. Procedure

The whole experiment took ~ 1 h. At the beginning of the experiment, sociodemographic data, education level, abdominal circumference, and the number of falls in the previous year were recorded in an individual information sheet. Data on weight, height, body mass index (BMI) and abdominal circumference were also obtained during the experiment. The history of falling was recorded in the individual information sheet. We defined a “fall” as unintentionally coming to rest on the ground, floor, or other level with or without an injury. Participants with LBP also completed four questionnaires: 10-cm VAS; Oswestry Disability Index (ODI); MMSE; MoCA. Assessments were conducted in a brightly lit, safe and quiet physiotherapy room. The mean (SD) of all COP parameters (AP velocity, ML velocity, sway area, sway length) were used in data analyses. If participants could not complete a single task, they did not receive a dual-task assessment (Fig. 2).

2.3. Statistical analyses

Descriptive statistics were used to describe demographics. The independent *t*-test was employed to determine the difference between the LBP group and HC group with respect to demographic data. By adjusting the covariates of BMI and abdominal circumference, the data of postural performance in the SBT were assessed using a mixed model analysis of covariance. Thatis, the within-participant factors were postural difficulties (eyes-open, eyes-closed, or one-leg stance) and cognitive difficulties (none, auditory arithmetic task, or serial-7 s arithmetic task), and the between-participant factor was group (LBP or HC). Dependent variables were the mean values of three trials of all COP parameters in each condition and cognitive-task accuracy. *Post hoc* pairwise comparisons with the Bonferroni adjustment were applied for significant main or interaction effects. The Greenhouse–Geisser correction was used if Mauchly’s test of sphericity was violated. Analysis of covariance (ANCOVA) with the covariates of BMI and abdominal circumference was conducted to test cognitive performance in the SBT. Studies haveshown that the sway length and sway area are valid fall-risk predictors and a holistic analysis of postural stability[21–22]. The sway area and sway length were selected to explore the associations between the COP parameters and the number of falls. $P < 0.05$ was considered significant in all statistical tests. Data were analyzed using SPSS v23.0 (IBM, Armonk, NY, USA).

3. Results

3.1. Participants

All study participants were female. There were no significant differences in age, weight, or height between the two groups ($P > 0.05$ for all) (Table 1). However, the LBP group had significantly higher BMI and abdominal circumference, and more falls in the previous 12 months (Table 1).

Table 1
Demographic characteristics of the two groups

Characteristic	LBP (n = 20)	HCs (n = 20)	*t*	*P*
Age (years)	64.90 (3.33)	63.20 (2.33)	0.87	0.38
Sex	Female	Female	—	—
Hand dominance	Right	Right	—	—
Height (m)	1.57 (0.04)	1.58 (0.03)	−0.28	0.77
Weight (kg)	58.25 (5.18)	55.80 (3.54)	1.74	0.89
MMSE	29.05 (0.94)	29.00 (0.97)	0.16	0.87
MoCA	26.65 (0.87)	27.20 (1.19)	−1.65	0.10
Body mass index (kg/m^2)	23.43 (1.97)	22.34 (1.17)	2.15	0.03
Abdominal circumference (cm)	87.40 (8.78)	81.20 (3.17)	2.96	0.05
Falls in the previous 12 months	0.80 (0.76)	0.35 (0.58)	2.08	0.04
Pain duration (years)	13.40 (9.90)	Not applicable		
Highest VAS pain intensity	8.00 (1.37)	Not applicable		
Oswestry Disability Index (%)	30.09 (9.04)	Not applicable		
Numbers in brackets denote SD.				
LBP: low back pain, HCS: health control, MMSE: Mini-Mental State Examination ,MoCA: Montreal Cognitive Assessment ,VAS: visual analog scale				

3.2 Postural performance in the SBT

Five participants in the LBP group could not complete the one-leg stance in a single task or dual task, so the data of 15 participants with LBP were used in the mixed model repeated-measure ANCOVA. Table 2 shows the mean (SD) of COP parameters in different combinations of postural difficulty and cognitive difficulty. Table 3 presents a summary of ANCOVA results for all data of postural performance in the SBT.

With regard to balance performance (at $F(1, 31)$ for all) the covariate of BMI [AP velocity: $F = 1.122$, $P = 0.298$, $\eta^2p = 0.035$], [ML velocity: 0.076, 0.784, 0.002], [sway area: 0.115, 0.737, 0.004], [sway length: 0.454, 0.505, 0.014] and abdominal circumference [AP velocity: 1.039, 0.316, 0.032], [ML velocity: 0.516 0.478, 0.015], [sway area: 0.003, 0.956, 0.000], [sway length: 0.010, 0.920, 0.000] were not significant in all COP parameters. The COP parameters (at $F(1, 31)$ for all) were significant between the two groups [AP velocity: $F = 49.260$, $P < 0.001$, $\eta^2p = 0.614$; ML velocity: 115.997, < 0.001, 0.789; sway area: 82.414, < 0.001, 0.727; sway length: 48.600, < 0.001, 0.611]. The main effects of postural difficulty were significant in AP velocity [$F(1.297, 40.197) = 8.254$, $P < 0.005$, $\eta^2p = 0.210$], ML velocity [$F(1.202, 37.250) = 3.920$, < 0.001, 0.112], and sway length [$F(1.425, 44.175) = 3.128$, 0.069, 0.092], but not significant in sway area [$F(1.160, 35.972) = 1.662$, 0.207, 0.051]. The main effects of cognitive difficulty were not significant in all COP parameters [AP velocity: $F(1.607, 49.823) = 0.192$, $P = 0.778$, $\eta^2p = 0.006$; ML velocity: $F(2, 62) = 2.554$, 0.086, 0.076; sway area: $F(2, 62) = 0.518$, 0.582, 0.016]; sway length: $F(2, 62) = 0.415$, 0.653, 0.013].

The group × postural difficulty × cognitive difficulty effect was only significant for sway length [$F(2.615, 81.067) = 3.044$, $P = 0.040$, $\eta^2p = 0.089$]. *Post hoc* analyses showed that the LBP group had a larger sway length than that in HCs in the dual task ($P < 0.050$) but not in the single task, when standing on a force platform with eyes-open or eyes-closed. However, the LBP group showed a larger sway length than that in HCs in the single task and dual task ($P < 0.050$) in the one-leg stance. The group × postural difficulty effect was significant in all COP parameters [AP velocity: $F(1.297, 40.197) = 6.862$, $P = 0.008$, $\eta^2p = 0.181$; ML velocity: $F(1.202, 37.250) = 17.359$, < 0.001, 0.435; sway area: $F(1.160, 35.972) = 9.142$, 0.003, 0.228; sway length: $F(1.425, 44.175) = 7.198$, 0.005, 0.188]. *Post hoc* analyses showed that the LBP group had larger COP parameters than that of HCs in three tasks of different postural difficulties ($P < 0.050$). The cognitive difficulty × group effects were significant for ML velocity [$F(2, 62) = 3.448$, $P = 0.038$, $\eta^2p = 0.100$], sway area [$F(2, 62) = 15.065$, < 0.001, 0.327], sway length [$F(2, 62) = 5.346$, 0.007, 0.147] and marginally significant for AP velocity [$F(1.607, 49.823) = 2.994$, 0.070, 0.089]. *Post hoc* analyses showed that the LBP group had larger COP parameters than that of the HC group in three tasks of different cognition difficulties ($P < 0.050$). Only participants with LBP showed larger COP parameters in dual tasks than those undertaking a single task ($P < 0.050$), which was not observed in HCs. Both groups showed larger COP parameters in the dual task with higher cognitive difficulty than that in the dual task with lower cognitive difficulty ($P < 0.001$). No significant postural difficulty × cognitive difficulty effect was found in COP parameters. These results suggested that, compared with healthy older people, older people with LBP had poor postural performance (as reflected by larger COP parameters) regardless of any postural or cognitive difficulties. Compared with the single task, the PC of participants with LBP was impaired in the dual task, even though the difficulty level of the cognitive task was low. The postural balance of HCs, however, was impaired when the difficulty level of the cognitive task was high.

Table 2
Performance in different combinations of postural difficulty and cognitive difficulty for the two groups

Conditions		AP velocity		ML velocity		Sway area		Sway length	
		LBP	Control	LBP	Control	LBP	Control	LBP	Control
Single task	Eyes-open	10.80 (2.48)	9.85 (2.81)	7.67 (2.10)	6.55 (2.37)	228.07 (60.157)	204.85 (65.07)	309.20 (78.18)	302.55 (65.73)
	Eyes-closed	15.13 (3.29)	14.50 (3.67)	10.53 (2.23)	10.65 (4.06)	403.73 (85.68)	382.50 (123.51)	498.73 (74.48)	527.85 (157.63)
	One-leg stance	29.80 (8.81)	23.50 (5.54)	27.53 (6.44)	17.95 (4.39)	973.33 (231.23)	720.75 (261.76)	1216.00 (203.46)	881..35 (223.15)
Dual task	Eyes-open + task 1	12.67 (2.09)	8.25 (1.37)	8.73 (1.90)	5.75 (1.02)	388.27 (75.48)	150.80 (44.30)	427.00 (86.19)	253.85 (52.77)
	Eyes-closed + task 1	16.67 (1.67)	11.60 (1.63)	13.07 (2.05)	9.05 (1.63)	527.80 (96.17)	316.55 (68.39)	558.73 (51.347)	412.65 (94.09)
	One-leg stance + task 1	34.40 (4.98)	27.10 (3.72)	32.80 (5.03)	24.35 (3.99)	1353.80 (330.22)	892.80 (196.00)	1190.33 (298.58)	969.75 (152.37)
	Eyes-open + task 2	19.53 (3.24)	16.05 (3.15)	14.20 (2.24)	12.30 (2.71)	563.93 (113.92)	291.95 (79.60)	600.87 (127.38)	413.55 (123.30)
	Eyes-closed + task 2	21.20 (3.38)	18.10 (1.83)	15.87 (1.72)	13.85 (1.78)	698.27 (73.87)	383.05 (72.04)	703.93 68.56)	501.20 (55.02)
	One-leg stance + task 2	38.27 (6.71)	31.90 (3.82)	35.20 (4.66)	28.00 (2.73)	1647.47 (299.05)	1227.65 (243.06)	1506.00 (240.32)	1213.30 (198.42)
	One-leg stance + task 2	37.69 (6.88)	31.9 (3.8)	35.13 (4.5)	28.00 (2.73)	1621.69 (306.76)	1227.65 (243.06)	1490.63 (254.62)	1213.30 (198.42)
Numbers in brackets denote SD.									

AP: anteroposterior, ML: mediolateral, task 1: auditory arithmetic task, task 2: serial-7 s arithmetic task

Table 3
Summary of F and P values for four COP parameters

Independent variable	**AP velocity**		**ML velocity**		**Sway area**		**Sway length**	
	F	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Main effect								
Group	49.260	< 0.001	115.997	< 0.001	82.414	< 0.001	48.600	< 0.001
Postural difficulty	8.254	0.004	3.920	< 0.001	1.662	0.207	3.128	0.069
Cognitive difficulty	0.192	0.778	2.554	0.085	0.518	0.582	0.415	0.653
Interaction effect								
Group × postural difficulty	6.862	0.008	17.359	< 0.001	9.142	0.003	7.198	0.005
Group × cognitive difficulty	2.994	0.070	3.448	0.038	15.065	< 0.001	5.346	0.007
Postural × cognitive difficulty	0.527	0.654	1.001	0.387	0.536	0.610	1.682	0.183
Group × postural × cognitive difficulty	0.794	0.494	0.566	0.609	0.596	0.575	3.044	0.040
AP: anteroposterior ML: mediolateral								

3.3 Cognitive performance in the SBT

The cognitive performance results in the SBT are shown in Table 4.The covariates ofBMI ($F = 7.258$, $P = 0.011$), and abdominal circumference (11.123, 0.002) were significant in the condition of auditory arithmetic task with a one-leg stance. BMI and abdominal circumference, however, were not significant in other conditions ($P > 0.05$). After adjustment of the covariates of BMI and abdominal circumference, the LBP group showed lower percentage accuracy than that of the HC group only in the one-leg stance condition ($P < 0.05$). However, there wasno significant between-group difference in two-leg stance with eyes-open or eyes-closed ($P > 0.05$).

Table 4
Percentage accuracy of cognitive tasks with different postural tasks

	Cognitive performance			
	LBP (n = 20)	**HCs (n = 20)**	***F***	***P***
Eyes-open + task 1	0.94 (0.09)	0.96 (0.06)	0.011	0.916
Eyes-closed + task 1	0.98 (0.04)	0.98 (0.03)	0.810	0.374
One-leg stance + task 1	0.83 (0.07)	0.93 (0.07)	10.978	0.002
Eyes-open + task 2	0.91 (0.14)	0.91 (0.12)	0.383	0.540
Eyes-closed + task 2	0.98 (0.05)	0.96 (0.09)	0.941	0.339
One-leg stance + task 2	0.76 (0.18)	0.88 (0.15)	6.316	0.017
Numbers in brackets denote SD.				

3.4 Associations between COP parameters and the number of falls

The associations between the COP parameters in all conditions and the number of falls are shown in Table 5. Significant associations between sway area and sway length and the number of falls in a single task were shown only in the eye-closed condition. The correlations between sway area and the number of falls in dual task 1 (postural task and auditory arithmetic task) were significant in eyes-open and eyes-closed conditions. The correlations between sway length and the number of falls in dual task 2 (postural task and serial-7 s arithmetic task) were significant in the eyes-open, eyes-closed, and one-leg stance conditions. The other associations between the COP parameters and the number of falls were not significant ($P > 0.050$).

Table 5
Relationship between COP parameters in all conditions and the num

	SO_sway area	**SO_sway length**	**SC_sway area**	**SC_sway length**	**Sleg_sway area**	**Sleg_sway length**	**DO1_sway area**	**DO1_sway length**	**DC1_sway area**	**DC1_sway length**	**Dleg1_sway area**
rho	0.281	0.217	0.386*	0.482**	0.089	0.277	0.314*	0.267	0.323*	0.212	0.031
p	0.079	0.179	0.014	0.002	0.605	0.102	0.048	0.096	0.042	0.189	0.858

SO, single task with eyes-open; SC, single task with eyes-closed; Sleg, single task with one-leg stance; DO1, dual task (postural task and auditory arithmetic task) with eyes-open; DC1, dual task (postural task and auditory arithmetic task) with eyes-closed; Dleg1, dual task (postural task and auditory arithmetic task) with one-leg stance; DO2, dual task (postural task and Serial-7 s arithmetic task) with eyes-open; DC2, dual task (postural task and Serial-7 s arithmetic task) with eyes-closed; Dleg2, dual task (postural task and Serial-7 s arithmetic task) with one-leg stance.

4. Discussion

We examined the modulation effect of cognitive loads on the PC of older people with LBP. Load manipulations were successful in all experiments: participants' performed worse in the high-load task(task2) when compared to the low-load task(task1). Posture task were also meet our expectations:participants'performed worst in One-leg stance and performed best in rigid-surface eyes open at the three posture conditions. When cognitive task combined with postural task, the result was complicated. These results were consistent with our hypothesis. Compared with the single task, the PC of participants with LBP was impaired in the dual task, even though the difficulty level of the cognitive task was low. The PC of HCs, however, was impaired only if the difficulty level of the cognitive task was high. The performance in the LBP group weresupported by Sherafat et al[23]. They found significant differences between single-task and dual-task (auditory Stroop test as the concurrent cognitive) conditions in adult patients with LBP. Sherafat et al's study, however, did not employ different difficult levels of cognitive tasks. The potential reason for the dissociated performance of elderly LBP patients from the HC's performance was that the presence of pain may require attention and may compete for limited attentional resources[24]. Previous studies have shown pain was associated with poorer cognitive functioning in the domains of memory, mental flexibility, emotional decision making, and attention[25–27]. For instance, Weiner et al.[17] found cognitive performance in older adults with LBP to be lower than that in healthy older adults. In this study LBP group's attention capacity was reduced due to long-term pain. Thus, it was not enough attentional resources to complete PC task in dual tasks for the participants with LBP, sequentially leading to poor balance performance or motor behaviour. Nevertheless, the deficits in balance of healthy elderly people could be compensated by cognitive system in the dual task when the cognitive task was not difficult.

An impaired PC of healthy older people was only found at a high difficulty level of the cognitive task, which was consistent with those reported by Huxhold and coworkers[8]. They reported the postural stability of healthy older people to be enhanced in the dual-task with a digit choice reaction time task as the less difficult cognitive task than that in a single task, whereas those postural stability were reduced in the dual task with digit and spatial 2-back memory tasks as the more difficult cognitive task than single task. Marchese and colleagues[28], for instance, reported the inhibitory effects of verbal serial-7 s arithmetic tasks (counting backwards aloud in multiples of three) on postural stability. Conversely, Mak and collaborators[29] reported a facilitation effect of nonverbal tasks (auditory switch task) on the postural stability of healthy older participants. Our findings in the HC group were supported by the U-shaped model proposed by

Lacour and coworkers[5] to explain the relationship between PC and cognitive demand. In the U-shaped model, posture stability could be modulated by the consumption of attentional resources of the second task. If the second task requires a lower level of attentional resources, postural stability will increase for healthy participants. This phenomenon may be due to a shift in the focus of attention away from PC, thereby increasing the automatic processing of posture[30–31]. However, if the consumption of attentional resources of the second task increases, postural stability would be reduced due to the limited capacity of the brain. In our study, the PC deficits of healthy older people were not observed in the dual task with a less difficult cognitive task due to the compensation from higher cognitive systems to a certain extent. However, the low-load attention task seemed to disturb, rather than facilitate, PC for older patients with LBP due to their impaired PC performance.

We also showed that, compared with healthy older people, older people with LBP had poor PC as reflected by larger COP parameters regardless of postural or cognitive difficulties. These findings are consistent with our hypothesis and supported by the work of Mazaheri and colleagues[32]. They reported a LBP group to have worse PC (as reflected by larger postural sway) than that of HCs in a dual task (two-leg stance and counting digits). Even though the sample population in their study was adult patients with LBP, the capacity of sensory, motor, and cognitive processing decreases with aging[33–34]. For instance, Lee and coworkers[31] investigated postural responses to sudden release of a pulling force in older adults with and without LBP: the LBP group had worse PC than that of HCs. Thus, compared with PC in HCs, the impaired PC of older participants with LBP was most likely due to decreased motor and cognitive functions[35].

The cognitive performance of the LBP group in the SBT was impaired compared with that in the HC group only in the one-leg stance rather than other two postural tasks. This finding was consistent with those reported by Etemadi[13] et al and Salavati[14]et al. Both of these two studies showed the LBP group had worse performance in cognitive task compared to the control group.In Etemadi[13] et al's study the reaction times of cognitive task of LBP participants were slower than those of the controls in all conditions. While in Salavati[14] et al's study more cognitive errors were found in the LBP group than control group when the cognitive task was most difficult with higher postural difficulty. The one-leg stance has been found to be a more challenging balance condition[36] because it may require more cognitive resources to maintain balance compared with that of other postural tasks (eyes-open and eyes-closed). The one-leg stance would become more difficult when carrying out two tasks simultaneously due the limits of cognitive capacity[37]. In the present study, older participants with LBP showed impaired postural stability compared with that in HCs at three levels of postural tasks, and cognitive performance was impaired only in the one-leg stance. The potential reason was that increasing the difficulty of the postural/cognitive task in the dual-task would result in insufficient cognitive resources to be allocated to posture tasks for people with LBP, especially if the postural task was more difficult[38].

In the present study, significant associations in the single task were shown only in the eye-closed condition. These findings are supported by a study suggesting vision to be an important risk factor for falling[19]. More associations between sway area/sway length and the number of falls were significant in dual-task conditions than in single-task conditions. This finding is consistent with that in a study reporting dual-task testing to be more strongly associated with fall risk than single-task testing[39]. The reason for these findings is that the dual-task paradigm is similar to the activities of daily living, which require cognitive and motor tasks to be undertaken simultaneously.

Our study addresses several of the gaps in knowledge and limitations of previous research in this area. Few studies have employed a dual-task model to assess PC in older people with LBP. In particular, we combined different levels of posture tasks and cognitive tasks. Given the importance of a dual-task performance for independent living in old age, this emerging research area, which relates attention and PC, has become a “hotspot”. However, PC impairment and body instability in older adults with LBP resulting from deficits in the allocation of attention have been considered only recently[40]. Our results suggested that chronic LBP seems to have an interaction with cognitive functions, and sequentially result in postural instability.

Our study had four main limitations. First, our study had a cross-sectional design. Prospective cohort studies are needed to investigate the causal relationship between cognitive loads in postural tasks and the number of falls. Second, we used only behavioral PC to examine the modulation effect of cognitive loads on PC. Future studies should employ electromyography and/or electroencephalography to explore the underlying neural mechanism. Third, this study do not assess the effects of cognitive load on dynamic balance,which also reflect the postural control of older people.Finally, all the participants recruited in the present study were female, which hampered the generalizability of our findings.

5. Conclusions

We revealed that, compared with HCs, older participants with LBP showed impaired PC regardless of the difficulties of postural tasks (especially during concurrent postural and cognitive tasks). Our findings shed light on how cognitive loads modulate PC and suggest that dual-task training could be an effective rehabilitation intervention in older people with LBP.

Abbreviations

LBP: low back pain, PC: postural control,HCS: health control,MMSE: Mini-Mental State Examination ,MoCA: Montreal Cognitive Assessment ,VAS: visual analog scale, AP: anteroposterior, ML: mediolateral, STB:Static balance test,SO:single task with eyes-open,SC:single task with eyes-closed,Sleg:single task with one-leg stance, DO1:dual task (postural task and auditory arithmetic task) with eyes-open, DC1:dual task (postural task and auditory arithmetic task) with eyes-closed, Dleg1:dual task (postural task and auditory arithmetic task) with one-leg stance,DO2:dual task (postural task and Serial-7s arithmetic task) with eyes-open, DC2:dual task (postural task and Serial-7s arithmetic task) with eyes-closed, Dleg2:dual task (postural task and Serial-7s arithmetic task) with one-leg stance.

Declarations

Ethics approval and consent to participate

This study was conducted as a single-blind randomized controlled trial (i.e., where the data analyzer was blind to the study). The study protocol was approved by the ethics committee of the First Affiliated Hospital of Sun Yat-sen University(grant number#2019469) in Guangzhou, China, in accordance with the Declaration of Helsinki.Written informed consent was obtained from all participants and the rights of the participants were protected.

Consent for publication

All authors approved the final version to be published

Competing interests

The authors declare that they have no competing interests

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Author Contributions

C.H.W: conceived the design,performed the literature review, L.G: analyzed the data, wrote the first draft of the article.Q.H.Y : collected the data. revised the first draft. H.J.H:analyzed the data .X.L:collected the data.S.Y.Z:collected the data.S.S.Z:collected the data.All authors approved the final version of the manuscript.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request

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Figures

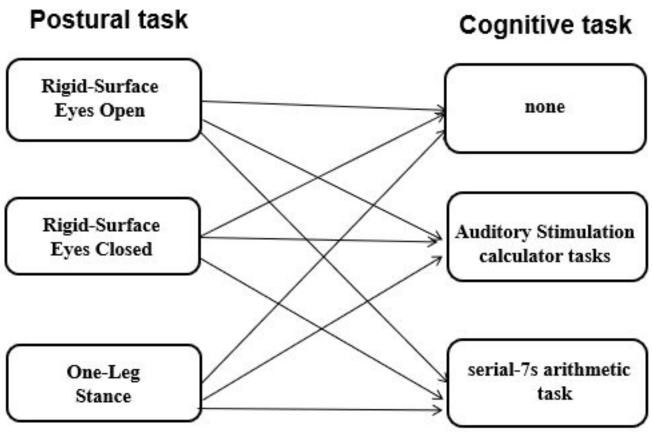

Figure 1

Combinations of postural tasks and cognitive tasks

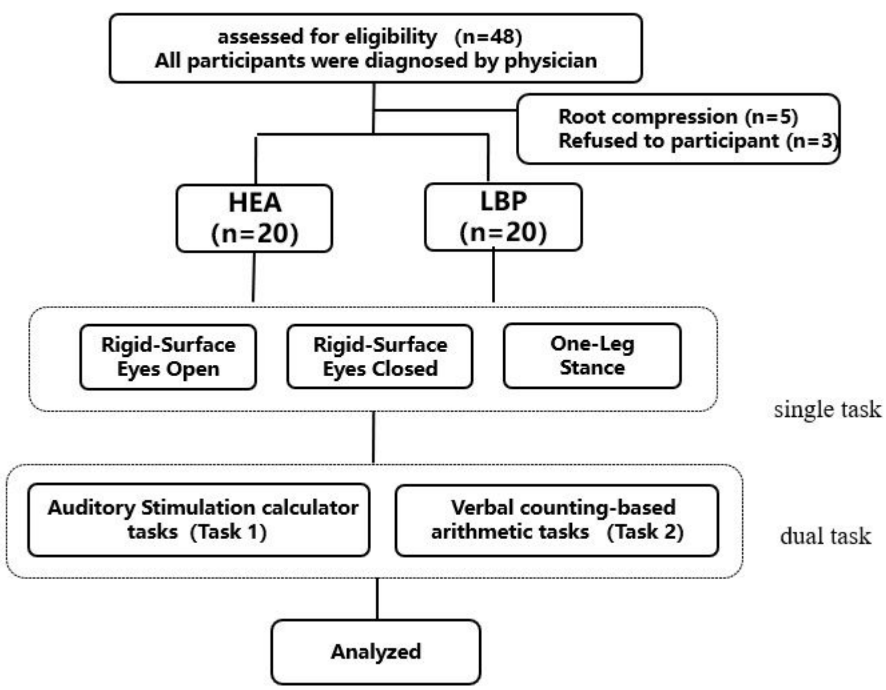

Figure 2

Flowchart showing participant screening and the experimental protocol.