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ORIGINAL ARTICLE

Walking and Talking in Maintenance Hemodialysis Patients

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Abstract

Objectives: To investigate whether there is a reduction in walking with the simultaneous performance of a cognitive task (ie, dual-task cost [DTC]) in persons undergoing hemodialysis (HD), and whether it is greater in persons undergoing HD compared with age-matched controls.
Design: Cohort.
Setting: University research laboratory.
Participants: Persons undergoing HD (n=14; 5 women, 9 men; mean age ± SD, 50.0±11.8y) and age-matched controls (n=14; 4 women, 10 men; mean age ± SD, 48.5±10.1y) participated in the investigation.
Interventions: Not applicable.
Main Outcomes Measures: Participants walked at a self-selected pace on an electronic pathway, which recorded spatiotemporal parameters of gait, in 4 separate trials and completed a cognitive task in the last 2 trials. The DTC was quantified as the change in spatiotemporal parameters of gait from baseline to the cognitive trials.
Results: The HD group had a greater decrease in walking function during the cognitive task, with DTC ranging from 6% to 14%. On average, walking velocity decreased to less than 1m/s in HD patients during the cognitive condition. Baseline walking velocity was found to be moderately correlated with the magnitude of DTC of cadence and step time ($\rho=-.44$ and .46; P values $<.05$).
Conclusions: Persons undergoing HD have greater interference between walking and talking compared with controls. Difficulty walking while thinking has implications for everyday life and may be related to the risk of falls. Further work is necessary to determine other contributing factors to elevated DTC in HD patients, and whether DTC can be reduced with targeted interventions.
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Chronic kidney disease (CKD) is a progressive disorder typically characterized by chronic inflammation that affects approximately 13% of adults in the United States.[1] The prevalence of patients with advanced CKD requiring maintenance hemodialysis (HD) therapy is increasing rapidly.[1] HD patients experience a number of comorbidities that are mechanistically linked. These comorbidities include muscle catabolism and wasting,[2] reduced muscle strength and physical function,[3] and bone mineral disease.[4] A common manifestation of these comorbid conditions is a phenotype of increasing frailty characterized in part by a decline in walking speed as the disease progresses.[5-9]

It is traditionally thought that impaired walking in HD patients results from declines in physiologic function such as muscle weakness.[3,10] However, it is becoming increasingly apparent that cognitive (dys)function also may play a role in walking impairment.[11] Cognitive (dys)function may impact walking as a result of cognitive-motor interference. Cognitive-motor interference refers to the phenomenon of reduced performance of a motor task with the simultaneous performance of a cognitive task.[11] The reduction in the motor performance caused by a concurrent performance of a cognitive task is termed dual-task cost (DTC).

Although DTC has been examined in numerous special populations, there have been no examinations of DTC in HD patients. It is consistently observed that groups with impaired walking such as persons with Parkinson's disease,[12,13] multiple sclerosis,[14] Alzheimer disease,[15,16] and stroke[17] have elevated DTC compared with groups without impairment. It has been suggested that both motor and cognitive impairment contribute to DTC in various populations.[18,19]

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Given that both cognitive[20] and walking impairment[3,10] are common in HD patients, it is logical to speculate that DTC will be elevated in HD patients compared with healthy controls.

Determining DTC in HD patients has clinical significance in that the DTC of walking has been shown to be predictive of recurrent falls in older adults[21] and associated with fall risk in persons with Parkinson's disease.[22] Additionally, if walking impairments result in part from cognitive-motor interference, the rehabilitative processes to maximize walking function would be distinct from those pursued if walking impairment is simply to the result of physiologic impairment. Therefore, the purpose of this investigation was to examine the DTC of walking in persons undergoing HD compared with healthy controls.

Methods

Participants

Fourteen community-dwelling, ambulatory HD patients (10 men, 4 women; mean age ± SD, 50.0±11.8y) who were receiving thrice weekly HD and 14 age-matched controls (9 men, 5 women; mean age ± SD, 48.5±10.1y) participated in this investigation. Control participants were included if they were free of chronic disease (eg, diabetes mellitus) and neuromuscular dysfunction (eg, stroke) and had no history of falling in the past 12 months. Exclusion criteria for HD patients included coronary heart failure, chronic obstructive pulmonary disease, and persistent hemoglobin levels <10g/dL, and HD patients must have been receiving dialysis for >3 months.

Procedures

On arrival to the laboratory, the experimental procedures were discussed with the participants, who then read and provided written informed consent approved by the local institutional review board. Participants further provided demographic information, and we measured their height and weight using a scale stadiometer. To minimize variation associated with dialysis, all testing occurred 22 to 26 hours postdialysis.

Participants next completed 4 walking trials down a 7.9-meter GAITRite[a] electronic walkway at a self-selected, comfortable pace. Participants began each trial 1.5 meters in front of the mat and walked 1.5 meters past the end of the mat to minimize acceleration and deceleration during each trial. Participants completed the first 2 trials with no cognitive task and the last 2 trials with a simultaneous cognitive task. Participants rested 30 seconds between trials.

The cognitive task was a modified word list generation (WLG) task. The modified WLG has been used to examine DTCs in previous research in special populations.[14] The modified WLG task involved participants stating as many words in a certain category (eg, fruits, words that began with the letter "D") during the walking task. The first dual-task trial used a semantic word generation task (ie, participants were instructed to list as many fruits and vegetables as possible when walking on the mat), while the second dual-task trial used a phonetic word generation task (ie, participants were asked to name as many words beginning with the letter "D" as possible when walking on the mat). The use of both semantic and phonetic tasks minimized any potential for a learning effect. The number of words uttered in each trial was recorded and normalized to walk time.

For a given trial, the GAITRite software calculated the normalized velocity (velocity divided by leg length) along with step length, step time, step width, percentage of gait cycle spent in double-support phase (double support), and percentage of gait cycle spent in swing phase (swing) for each individual leg. For brevity, we averaged each parameter across legs. Traditionally, step length and swing phase percentage are associated with propulsion, while step width and double-support percentage are associated with walking stability.

DTC was determined for each variable as the difference between single task and dual task, divided by dual-task performance, multiplied by 100. Consequently, a positive DTC indicates a decrease in performance for velocity, cadence, step length, and swing phase. A negative DTC indicates a decrease in performance for step time and percentage of gait cycle spent in double support.

Statistical analysis

Statistical analyses were conducted in SPSS version 17.0.[b] To determine differences between HD and control groups, a chi-square test was conducted for the categorical variables (ie, sex), and an independent sampled *t* test was performed for continuous variables. To improve reliability of the measures, the average of the parameters for each walking condition was used in the analysis. The average of the WLG task was also used in analyses. To determine whether there was an overall DTC for each variable (ie, significantly different than 0) within each group, single-sample *t* tests were used. To determine whether a preexisting difference in walking performance was related to DTC, Spearman correlations were performed between baseline velocity and DTC of the spatiotemporal parameters across the entire dataset. To determine whether words uttered was related to DTC, Spearman correlations were performed across the entire dataset. For all analyses, significance was defined as $P \leq .05$. The magnitude of the effect size was determined by Cohen's *d*. Cohen's *d* was calculated by subtracting the group means for each variable and dividing by the pooled SD for each variable. For Cohen's *d*, effect sizes of 0.2, 0.5, and 0.8 were considered small, moderate, and large effects, respectively.[23]

Results

The primary cause of CKD in the HD group was hypertension (n=7), followed by type 2 diabetes (n=4), type 1 diabetes (n=1), nephritis (n=1), and unknown (n=1). There were no significant differences in age, height, weight, body mass index, and sex between the HD and control group (table 1).

The spatiotemporal parameters in the baseline condition are presented in table 2. As expected, the HD group walked slower, took fewer steps, took shorter steps, spent a greater percentage of the gait cycle in double stance, and spent a smaller percentage of the gait cycle in the swing phase as compared with age-matched controls. The HD group also had narrower steps than the control group. The group differences in walking persisted in the cognitive trials (table 3).

List of abbreviations:

CKD **chronic kidney disease**
DTC **dual-task cost**
HD **hemodialysis**
WLG **word list generation**

Table 1 Participant demographics

Variables	Controls	HD	P
Age (y)	48.5±10.1	50.0±11.8	.719*
Height (cm)	172.9±0.08	170.6±0.07	.420*
Weight (kg)	86.4±14.1	99.4±24.5	.098*
BMI (kg/m^2)	29.1±5.8	34.2±8.2	.070*
Sex (F/M)	5/9	4/10	.686†
Months on dialysis	NA	51.6±36.5	NA
WLG (no. of words/s)	1.24±0.36	0.90±0.33	.024*

NOTE. Values are mean ± SD, n, or as otherwise indicated.
Abbreviations: BMI, body mass index; F, female; M, male; NA, not applicable.
* Significance determined by an independent sample *t* test.
† Significance determined by a χ^2 test.

Both groups demonstrated DTCs that were significantly different than zero for velocity, cadence, step length, and step width (*P* values <.05) (table 4). Only the HD group had a significant DTC for step time (*P*<.05). Neither group demonstrated a significant DTC for percentage of gait cycle in double support or swing phase (*P* values >.05).

The words uttered normalized by ambulation time during the cognitive trial was lower in the HD group (.90 words/s) than in the control group (1.24 words/s) ($t_{1,24}=-2.4$; $P=.02$). There were significant group differences in DTC for velocity, cadence, and step time, with the HD group having larger magnitude DTCs than the control group (*P* values <.05) (see table 4). The overall effect sizes of these differences were large in magnitude ranging from .80 to .98.

To examine factors related to DTC, correlation analysis was conducted. To determine whether baseline walking function was related to DTC, correlations between baseline walking velocity and DTC were computed. Overall, significant correlations were found only between baseline walking velocity and DTC in step time and cadence ($\rho=.46$ and $-.44$; *P* values <.05). To determine whether cognitive function was related to DTC, correlations between words uttered and DTC were conducted. There were no significant correlations (*P* values >.05).

Discussion

The current investigation examined the effect of a simultaneous performance of a cognitive task on walking performance (eg, DTC) in patients receiving HD compared with healthy controls. The novel observation was that HD patients had a greater DTC than age-matched controls. To our knowledge, this is the first report concerning cognitive-motor interference in HD patients. It implies that the walking impairment prevalent in HD patients is not completely physiologic in nature but has some cognitive component.

Previous research has demonstrated that HD patients have a phenotype of increasing frailty characterized in part by a decline in walking speed.[5-10] Consistent with this observation, HD patients in the present study had a significantly slower walking speed compared with healthy controls in the baseline condition. Traditionally, the impaired walking observed in HD patients has been suggested to stem from physiologic factors such as muscle weakness.[3,10] However, the elevated DTC observed in the HD patients raises the possibility that walking impairments are also influenced by cognitive dysfunction.

There are several potential reasons why the HD group had a larger DTC than healthy controls. It has been suggested that DTC is related to cognitive function in older adults[18,19,24] as well as persons with Parkinson's disease.[22] Many CKD comorbidities such as inflammation, oxidative stress, diabetes, malnutrition, and hypertension may contribute to cognitive impairments.[20] In addition, the large fluid shifts that occur during the HD procedure lead to hypotension, resulting in cerebral ischemia and acute deficits in cognition.[25] These acute deficits may have more chronic implications and further contribute to reductions in cognition. As a result, it is estimated that as many as 75% of HD patients have cognitive impairments.[20] Consequently, it is possible that impaired cognitive function contributes to elevated DTC in HD patients. The lower number of word utterances in the HD group is compatible with this notion. However, the number of words uttered was not associated with DTC. Unfortunately, no data pertaining to cognitive function were collected in the current investigation. Consequently, any association between cognitive function and DTC in HD patients is speculative at this point. Additional research is necessary to determine whether cognitive function relates to DTC.

DTCs have also been shown to be related to walking impairment in various clinical populations.[14,18,19] Congruent with this notion, HD patients in the current investigation did indeed have worse walking performance compared with age-matched healthy controls, and significant associations between baseline walking velocity and step time and cadence DTC were noted. It is important to note that DTCs were expressed as percent changes in spatiotemporal parameters, which theoretically should make the observed changes independent of baseline values.

Elevated DTC in HD patients was not found in all spatiotemporal parameters. There was no group difference in DTC for double support and step width. Double support and step width are both parameters that are associated with gait stability. Indirectly,

Table 2 Spatiotemporal gait parameters at baseline as a function of group

Variables	Control	HD	P	Cohen's *d*
Velocity (cm/s)	135.4±16.8	100.3±24.7	<.01	−1.7
Cadence (steps/min)	112.4±10.4	100.1±12.6	<.01	−1.1
Step length (cm)	72.35±6.59	59.70±12.7	<.01	−1.3
Step width (cm)	73.50±6.33	62.05±11.7	<.01	−1.2
Step time (s)	0.5±0.1	0.6±0.1	.02	−0.9
Double support (% GC)	28.9±3.0	34.5±6.8	.01	1.0
Swing phase (% GC)	35.7±1.8	32.9±3.5	.01	−1.0

NOTE. Values are mean ± SD or as otherwise indicated. *P* value and Cohen's *d* relate to group differences.
Abbreviation: % GC, percent gait cycle.

Table 3 Spatiotemporal gait parameters during walking and talking condition as a function of group

Variables	Control	HD	*P*	Cohen's *d*
Velocity (cm/s)	127.7±22.0	86.7±25.1	<.01	−1.7
Cadence (steps/min)	109.2±12.5	91.6±12.6	<.01	−1.4
Step length (cm)	70.2±7.7	55.9±12.8	<.01	−1.4
Step width (cm)	71.3±7.4	58.6±11.5	<.01	−1.3
Step time (s)	0.6±0.1	0.7±0.1	<.01	−1.0
Double support (% GC)	28.6±3.0	34.5±6.5	<.01	1.2
Swing phase (% GC)	35.8±1.6	32.8±3.3	<.01	−1.2

NOTE. Values are mean ± SD or as otherwise indicated. *P* value and Cohen's *d* relate to group differences.
Abbreviation: % GC, percent gait cycle.

this observation suggests that HD patients maintain gait stability while performing a challenging task (walking and thinking). This does not imply that HD patients were stable (HD group did have elevated double support compared with controls), but rather that their stability did not change during the dual-task condition. Additionally, the unique impact of the DTC on various walking parameters is congruent with the notion that stability (ie, step width) and propulsion (ie, step length) parameters result from different neural pathways.[26]

Another novel observation was that the HD group had narrower steps than the control group. It is commonly observed that individuals with gait impairments, such as older adults[27] and persons with multiple sclerosis,[28] have greater step width than control groups. There are several reasons why the HD group had narrower steps. It is possible that persons who were undergoing HD walked with narrower steps because of the constraints of walking on the GAITRite walkway, while the control group did not. Another potential explanation is that the HD group had excessive hip adductor tone, causing them to walk with a narrower stance. Given that no data were collected on adductor tone, this notion is merely speculation. Further research focusing on step width in persons undergoing HD is needed.

Significance of DTC

Regardless of the factors contributing to DTC in HD patients, the significantly greater DTC observed in HD patients presents a significant concern. An approximately 14% reduction in walking velocity would most likely negatively impact activities of daily living (eg, grocery shopping or crossing a street) and quality of life. Indeed, walking velocity is often seen as a correlate of physiologic function given the demands it places on multiple organ systems, with relatively lower gait speeds being associated with poor health and reduced life expectancy.[29] Persons undergoing HD are often characterized as frail based in part on their slow gait.[9] Along these lines, a potential interpretation of reduced gait speed during the cognitive trials for the HD group is increased frailty. Additionally, the DTC of walking has been linked to recurrent falls in older adults[21] and fall risk in patients with Parkinson's disease.[20] Although falls are a significant problem in persons undergoing HD,[30,31] the association between falls and DTC in HD is unknown.

Table 4 DTC as a function of group

Variables	Control	HD	*P*	Cohen's *d*
Velocity DTC (%)	5.8±8.4*	14.2±9.0*	.02	.96
Cadence DTC (%)	2.93±4.83*	8.4±6.7*	.02	.93
Step length DTC (%)	3.0±4.9*	6.6±4.9*	.06	.74
Step width DTC (%)	3.0±4.7*	5.6±4.3*	.14	.58
Step time DTC (%)	−3.1±5.6	−9.2±7.2*	.02	−.98
Double support DTC (%)	1.0±2.6	−0.4±4.4	.34	−.36
Swing phase DTC (%)	−0.4±1.2	0.07±2.6	.52	.25

NOTE. Values are mean ± SD or as otherwise indicated. *P* value and Cohen's *d* relate to group differences.
* DTC significantly different than 0 within each group.

There is growing evidence that DTCs can be improved with specific training in various populations.[32,33] For instance, Silsupadol et al[33] demonstrated that older adults with balance impairments who received 4 weeks of progressive exercise training focusing on body stability exercises while simultaneously engaged in a cognitive task improved their DTC of walking. It is well known that walking function can be improved with various rehabilitation techniques in HD patients.[34,35] The benefits of rehabilitation on walking and the association between walking function and DTC suggest that DTC in HD patients could be partially minimized with traditional interventions and further reduced with interventions targeting DTC. In contrast to the research on the effects of mobility training on DTC, there is limited evidence that cognitive training will lead to reductions in DTC. Based on the notion that cognitive interventions can be beneficial to HD patients,[36] it is possible that cognitive training would reduce DTC in HD patients. However, this possibility requires scientific scrutiny.

Study limitations

A limitation of this study was that the non−dual-task test was completed before the dual task in all subjects, which may have induced fatigue in HD patients with low physical function. To minimize the impact of fatigue, we allowed participants to rest after each trial. Nevertheless, it is possible that during the dual-task test, HD patients were more fatigued than during the non−dual-task test. Moreover, the results of this study cannot be generalized for all patients with CKD because the participants in this study were patients with renal failure receiving maintenance HD therapy and likely have greater functional and cognitive declines than predialysis CKD patients. Therefore, future studies are needed to examine the relationship between CKD progression and gait DTC. Lastly, the lack of cognitive assessment in the current procedures is a limitation. Any association between DTC and cognition in persons undergoing HD is speculative and warrants investigation.

Conclusions

The novel finding of this investigation was a significantly greater DTC during walking in HD patients as compared with healthy controls. On average, walking velocity decreased to less than 1m/s in HD patients during the cognitive condition. Baseline walking velocity was found to be associated with the magnitude of DTC. However, further work is necessary to determine other contributing factors to elevated DTC in HD patients, and whether DTC can be reduced with targeted interventions.

Suppliers

a. CIR Systems, Inc, 376 Lafayette Ave, Suite 202, Sparta, NJ 07871.
b. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.

Keywords

Gait; Kidney diseases; Rehabilitation

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