



Türk Fizyoterapi ve Rehabilitasyon Dergisi

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THE EFFECT OF DUAL TASK ON CLINICAL BALANCE PERFORMANCE IN ATAXIA PATIENTS

RESEARCH ARTICLE

ABSTRACT

Purpose: The purpose of this study was to investigate the effects of concurrent cognitive and motor tasks on clinical balance performance of ataxic and healthy subjects.

Methods: A total of 50 subjects with and without ataxia were included. Timed performances during Single Leg Stance (OLS), Tandem Stance (TS), 360 degrees of Rotation, Timed Up & Go (TUG) and Four Square Step (FSS) tests were recorded without task, and with concurrent cognitive and motor tasks.

Results: Ataxic and healthy subjects had similar SLS and TS test performances, applied with cognitive tasks. Motor task negatively affected the performances of the ataxic patients. Motor and cognitive tasks during 360 DR and cognitive task during TUG tests reduced the performances of both groups. During FSS test, motor task reduced the performances of ataxic patients, while both tasks reduced the performances of the healthy subjects.

Discussion: The results point out the effects of cognitive and motor tasks during static and dynamic balance tests in ataxic and healthy subjects. These findings are considered to be useful while evaluating the balance function of the ataxic patients, and focus on the necessity of including concurrent tasks during the balance tests.

Key Words: Ataxia; dual-task; balance; stabilization.

ATAKSİLİ HASTALARDA ÇİFT GÖREVİN KLİNİK DENGİ PERFORMANSINA ETKİSİ

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Çalışmanın amacı, ataksili ve sağlıklı olgularda ek bilişsel ve motor görevlerin klinik denge performansına etkisini araştırmaktır.

Yöntem: Ataksi tanısı olan ve olmayan toplam 50 olgu çalışmaya alınmıştır. Tek ayak duruş, tandem duruş süreleri, 360 derece dönme, zamanlı kalk yürü ve dört kare adım testini tamamlama süreleri görevsiz, ek bilişsel görevle ve ek motor görevle tekrar edilerek süre kaydedilmiştir.

Sonuçlar: Ataksili ve sağlıklı olguların bilişsel görev sırasındaki tek ayak duruş ve tandem duruş performansları benzerdir. Motor ek görev ataksili olguların test performanslarını olumsuz etkilemiştir. 360 derece dönme testi performansı her iki grupta da hem bilişsel hem motor görevlerden, zamanlı kalk yürü testi performansı her iki grupta da bilişsel görevlerden olumsuz etkilenmiştir. Dört kare adım testi performansı ise ataksili olgularda sadece motor ek görevlerden etkilenirken, sağlıklı olgularda hem motor hem bilişsel görevler sırasında anlamlı olarak bozulmuştur.

Tartışma: Sonuç olarak; motor ve bilişsel görevler ataksili ve sağlıklı olguların statik ve dinamik denge testleri üzerine etkilidir. Bu sonuçlar ataksili hastaların denge fonksiyonlarının değerlendirilmesinde ek görevlerin kullanılmasının gerekliliğini göstermektedir.

Anahtar Kelimeler: Ataksi; çift görev; denge; stabilizasyon.

Introduction

Ataxia is a movement disorder resulting from dysfunction of the nervous system components which coordinate movement. Besides being a symptom, is also a neurologic disease creating problems in coordination, posture, gait and fluency of talking (1). In current studies, it is indicated that attention need is too much for postural control and may change depending on many factors such as difficulty of the task performed, age of the individual and balance abilities (2). Postural control is an automatic reflex controlled task about the control of the body's position in space for the purpose of maintaining balance, stabilization and orientation (3-5). Postural control problems are frequent in ataxic people and a patient with balance problem must rapidly achieve postural control in order to improve independence in daily activities and walking abilities.

Generally "dual-task" term is the ability of performing two task at the same time and dividing the attention between these tasks (6). 'Dual task performance involves the execution of primary task which is the major focus of attention and a secondary task performed at the same time' (7). Dual task model includes concurrent performance of two tasks in order to investigate the effects of attention needed for one motor task and a motor or cognitive task, on motor performance (8).

In the literature, there are studies investigating the effects of dual tasks on balance and walking parameters in patients with neurological diseases (such as Parkinson, Alzheimer, stroke). The results of these studies draw attention to disabilities of dividing attention. In those patients, besides automatic walking parameters, cadence, step length and walking speed during dual tasks were also found decreased, and time of double support time, postural instability and risk of fall increased (9-12).

Defining how the attention deficits affect balance performance and safety of the patient is an important issue in neurological rehabilitation (9, 13). In people with cerebellar ataxia dual task interference is particularly a noticeable problem because of the disruption of the cerebellum. The cerebellum plays a major role in motor control and

some cognitive functions such as attention and language. So effective planning of the rehabilitation requires identification of coexisting problems and underlying neurophysiologic mechanisms (14). However, dual-task performance of patients with ataxia is usually ignored in routine clinical evaluation (15). While former studies provide important information about dual-task deficits in patients with various neurological diseases, there is no information or comparable data about the effects of motor and cognitive tasks on balance and postural stability in ataxic patients in clinical settings.

Therefore, the aim of this clinical controlled study is to evaluate the effect of motor and cognitive tasks on clinical balance performance of patients with ataxia, by using practical, reliable and valid clinical tests. We pay attention to the fact that the tests are reflecting many activities of daily living, and be useful for rehabilitation planning.

Material and Method

Participants

Participants were recruited from Neurology Department of Hacettepe University. 110 patients with cerebellar ataxia screened from files before admission to the study. Out of 110 patients, 61 patients who were accepted to participate to the study were invited to attend to the study at Physiotherapy and Rehabilitation Department of the Faculty of Health Sciences. Inclusion criteria were; ability to ambulate independently and having similar disease severity (to assess disease severity we used the following stages: stage 0=no gait difficulties; stage 1=disease onset, as defined by onset of gait difficulties; stage 2=loss of independent gait; stage 3=confinement to wheelchair; stage 4=death. Based on this we included patients at stage 1 (16), having at least 24 scores from Mini Mental State Examination (MMSE), having no speech problem and being voluntary to join the study. Subjects with other neurological, orthopaedic and cardiovascular problems which could affect walking were excluded. A total 25 patient (12 men, 13 women) between the ages of 20-50 were eligible for the study.

Also 25 healthy, age and gender-matched cases

who were Hacettepe University staff or students of departments other than Physical Therapy and Rehabilitation, participated in the study as comparison group.

Method

All participants provided informed consent and the study was approved by the ethical committee of Hacettepe University. Mini Mental State Examination (MMSE) was applied in order to identify cognitive level at the beginning of the study. The severity of the disease of Ataxia patients was described by International Cooperative Ataxia Rating Scale (ICARS) (17-18). Demographic information, medical history and falling history (falling frequency, falling history and fear of falling) of the cases were recorded. Within the scope of clinical balance tests, single-leg stance, tandem stance, 360 degrees of rotation, timed-up and go test, four square step tests were performed by all cases, initially without task, and then with cognitive and motor tasks, respectively. Different cognitive and motor tasks used in all balance tests for the purpose of reducing learning effect.

Tasks given to participants are as follows:

Cognitive tasks

1. Counting the names of months backwards from December to January (a)
2. Counting the names the starting with letter "A" (b)
3. Counting backward aloud by threes from 100 (7, 19, 20)
4. Telling the number of the letters of the words physiotherapist tells
5. When physiotherapist says "blue", saying "no", when s/he says "red", saying "yes" (12)

* 1st and 2nd concurrent tasks are modified by inspiring from the studies in literatures
(a) counting back the days of the weeks; Morris et al. 2005 (21)
(b) counting the words the initial of which is F and S; Galletly ve Brauer 2005 (22).

Motor tasks

1. Taking three objects from the bag respectively (money, the keys, pencil) and putting them back in turn

2. Carrying a glass on tray (11, 23)
3. Opening and closing bag zipper
4. Transferring the ball from one hand to the other (a)
5. Buttoning up the shirt button

*4th concurrent task is modified by inspiring from the studies in literatures
(a) transferring the money from one hand to the other; O'Shea et al. 2002 (7)

Single Leg Stance Time

It is a clinical test evaluating static balance on foot and on the narrow support surface (24). Time of standing on dominant side foot was recorded in seconds. If single leg stance position was not possible without support, they were asked to take the position with a support and the time s/he can stand was calculated from the moment s/he left her/his hand. The test was finished for the individuals who could stand for 30 seconds. Cognitive task given during the test is counting the names of months backwards from December to January, motor task given during the test is taking three objects from the bag respectively (money, the keys, pencil) and putting them back in turn.

Tandem Stance time

It is a clinical test reflecting stability in mediolateral directions and postural maintenance in static position on narrow support surface (25). During evaluation, the cases were asked to maintain tandem stance in a way their dominant foot is in the back and the time they can stand was recorded. If they could not take the position without support they were asked to take the position with a support and the time was calculated from the moment he/she removed the hand. The test was concluded for the individuals who can stand in 30 seconds. Cognitive task given during the test counting the names the starting with letter "A", motor task given during the test is carrying a glass on tray.

360 Degrees of Rotation Time

360 degrees of rotation test is a short measuring of dynamic balance. The test requires transmitting body weight from one foot to the other and taking successive steps while maintaining the balance

while rotating one's own axis (26). The cases were asked to take one tour firstly to one direction, later to reverse direction on their own axis and the time passed was recorded. Cognitive task given during the test counting backward aloud by threes from 100, motor task given during the test is transferring the ball from one hand to the other

Timed up and go test completing time

Timed up and go test is a suitable test to evaluate functional mobility within the society and to show the changes in clinic (27). In our study, the subject was asked to sit on an armchair with his/her back against the chair and feet flat on the floor. He/she was then instructed to rise and walk as fast as possible to a mark on the floor 3 metres away, turn around, walk back to the chair and sit down again. Timing commenced on the word "start" and ceased once the subject's back of the chair. Cognitive task given during the test telling the number of the letters of the words physiotherapist tells, motor task given during the test is opening and closing bag zipper

Four Square Step Test

It is a test which is designed to examine ability to step over small objects and change direction within a clinical setting. The test is suitable for evaluating multi directional step instabilities of individuals having balance disorder and vestibular dysfunction (28). In four square step test, the subject stands in square number 1 facing square number 2. The aim is to step as fast as possible into each square in the following sequence. Square number 2, 3, 4, 1, 4, 3, 2. Both feet must make contact with the floor with each square. They were asked to take one tour clockwise and counter clockwise and the time passed was recorded (figure 1). Cognitive task given during the test is when physiotherapist says "blue", saying "no", when s/he says "red", saying "yes", motor task given during the test is buttoning up the shirt button.

Calculation of the dual-task deficit:

Reduced performance in the dual-task condition is described as dual-task deficit. Dual-task deficit may be expressed as a difference between single and dual task performance. According to Abertnethy (29); performance changes occurred

during the concurrent task are influenced by the rate of baseline performance. For that reason, the below mentioned formula is used in order to calculate dual task deficit and compare the deficits resulted from cognitive and motor tasks.

$$[(\text{Dual task performance} - \text{Single Task Performance}) \div \text{Single Task Performance}] \times 100$$

This calculation controls for baseline performance, and dual-task performance deficits are interpreted as percentages. This type of calculation allows comparison across individuals and also allows comparison over time when baseline performance may change.

At the beginning of the evaluation, the patients were informed about the test procedure and then asked to try it once. The evaluations were made by the same physiotherapist at the same place, in the afternoons. Subjects were told to wear their comfortable shoes during the tests. Eyes of the subjects were open during tests. An observer watched out the participants against risk of falling. Two minutes resting break was given at each test intervals. Each test was performed twice and mean values were recorded in seconds. The same materials were used while the participants were evaluated. In each test different cognitive and motor tasks were given in order to eliminate learning effect.

Statistical Analysis

For statistical analysis SPSS 15 windows-based analysis program was used. Quantitative and qualitative data were expressed as "Mean $\pm$ Standard deviation" and "%" respectively. For the sequential evaluations of the same group, Wilcoxon Matched Example Test was used and Mann-Whitney U test was used for inter-group comparison s. The level of significance was accepted as $p < 0.05$. According to the power analysis performed at 80%, it was determined that approximately 25 patients required to accomplish the study.

Results

Physical characteristics and MMSE scores of the groups were similar (all $p > 0.05$). (Table1). Mean disease duration of the ataxic patients was 6.58 years and mean ataxia severity scores were 17.52/100 according to ICARS (0-100), numbers

of falling were recorded as 2.56 falling/ 6 months (Table 1). 64 percent (16, 7F, 9M) of all subjects reported falling within the last 6 months. One of them (4%) reported once, 5 of them (20%) reported twice and 10 of them (40%) reported more than twice falling.

Without Task Balance Tests Performance

Times of completing static and dynamic balance tests were compared between ataxic and comparison groups. Results of SLT and TS tests were lower, and 360 DRT, TUG and FSST were higher in the ataxia group (all p 's<0.05). Balance test results are summarized in Table 2.

The Effects of Cognitive and Motor Concurrent Tasks on Performance

Static Balance Tests

Motor tasks decreased TST results, significantly ($p=0.019$) (Table 3).

Dynamic Balance Tests

Time of completing 360 DRT increased with cognitive and motor tasks in both groups (all p 's>0.05). Cognitive task increased TUG test value in ataxic and comparison subjects (all p 's>0.05). FSST test was completed in a longer time in ataxic group when performed with motor task ($p<0.013$). For subjects in the comparison group, time of completing FSST increased with both cognitive and motor tasks (all p 's>0.05) (Table 3).

Cognitive and Motor Task Deficits

Except FSST with cognitive task, deficit rates caused by concurrent tasks were similar between groups (all p 's>0.05) (Table 4). When we analyzed which task type led to more deficits in balance tests; in ataxia patients, it was found that motor task deficits were more obvious than cognitive task deficits in four square step test ($p=0.033$). On the other hand, in 360 degrees of rotation test, cognitive task deficit was more than motor task deficit ($p=0.001$).

In comparison group, it was seen that cognitive task deficit was more than motor task deficit in 360 degrees of rotation test ($p=0.008$) (Table 4, 5).

Discussion

The results of the study demonstrated that in

individuals with ataxia, static (SLS, TS) and dynamic (360 DR, TUG, FSST) balance performance was affected during concurrent tasks and this influence was more prominent especially during dynamic tests. On the other hand in healthy individuals, only dynamic performance is affected by the concurrent tasks.

For a patient with ataxia who have balance and stability problems, improving function and prevention of risks are important for the rehabilitation process. Falling risk is an important factor that leads to limitations in activities of daily living. In addition presence of fear of falling negatively effect the patient's social participation and reduces the quality of life. Therefore identification of necessities, determination of appropriate treatment and evaluating the results with appropriate outcome measures are important for the rehabilitation practice (30).

Previous researches were focused on the effect of dual-task performance on postural sway and gait characteristics. For this purpose computerized gait analyses and posturography were used (4, 23). Although these methods provide objective and reliable data, they require training, takes a long time, expensive equipments and laboratory setting. Therefore we preferred to use clinical tests in this study. The tests are easy to perform, does not require much time and equipment and can be used as training approach in the treatment program.

Static balance tests results showed that ataxic group was only affected by the cognitive and motor tasks when they perform tandem stance test. Tandem stance is a static balance test which reflects stability in the mediolateral direction and continuity in the static postural position in narrow support surface. Pajala et al showed that tandem stance test reflects the falling risk in elderly people (31). Morris et al studied the effects of cognitive tasks to some clinical balance tests such as stance in feet apart, feet together, one leg in front, tandem and single leg (21). He found that tandem stance significantly decreased in patients with a history of fall. So we suggest that tandem stance in dual-task performance is an easy and practical test which reflects the falling risk for ataxic patients in clinical setting.

Several researches showed that static activities such as sitting and standing requires less attention than dynamic activities such as walking (32, 33). In the other words, attention need changes according to the difficulty of the task (32). This study supports our findings that dual task conditions seem to have more impact on dynamic balance performance. An individual who has balance problems can be independent as long as he can maintain his functions successfully such as walking, turning, sitting and functions that contains dynamic equilibrium in activities of daily living. Therefore we used these clinical dynamic balance test for the purpose of understanding attention need and perceived risk of falls for different functions. In our study motor and cognitive tasks during 360 DR and cognitive task during TUG tests reduced the performances of both groups. During FSS test, motor task reduced the performances of ataxic patients while both tasks reduced the performances of the healthy subjects. So we suggest that, 360 turning, timed up and go and four square step test can reflect balance problems and risk of falling during the functional activities. Also these test can be used to determine the need for attention during dual task performance.

Unlike previous studies, we used deficit rates while comparing the effects of dual tasks on balance. Deficit rates enables us to evaluate dual task performance of the individuals through their own performance. The result of this study showed that, when the deficit ratio of healthy and ataxia cases are compared, both groups are affected from cognitive and motor tasks during the dynamic balance tests similarly. This interesting results shows us that dual tasks affect balance and stabilization in the same level during several activities in both ataxia and healthy cases. When we compared the two groups clinical balance test performance with or without cognitive and motor tasks; performance were worse in the ataxia group than the comparison group. This results shows us 'posture first principle is important in both ataxic and healthy individuals. When a person perform a dual task performance, attention would be directed to postural control in order to maintaining stability and protecting themselves against falling (34). This result is more prominent in ataxic patients.

These people are in a disadvantageous condition in daily activities (cross the roads in traffic lights, coordinating with moving staircase and automatic gate in shopping center etc.) which requires adequate timing and speed.

Furthermore, as a clinical aspect, in some tests, ataxia group's not giving importance to performing the concurrent task correctly due to their giving priority to protecting themselves against falling. It has been a factor which restricts fully understanding the deficit created in concurrent tasks by giving priority to preserving posture. We think that it is a significant limitation for our study not to evaluate the second task performance. It is considered that the researches which will be performed in the future should be evaluate second task performance as well as the first task.

This study provides information to the health professionals about effects of dividing attention on balance and stabilization performance, in community ambulatory patients with ataxia. Also the results pointed out the need for evaluation of concurrent motor and cognitive task performances by using simple and easily applicable tests in clinical settings, and improving dual task performance during treatment programs.

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Conflict of Interest Statement

The Authors declare that there is no conflict of interest.

REFERENCES

1. Bradley WG. Neurology in Clinical Practice: The neurological disorders. 6th ed. Taylor & Francis; 2004.
2. Woollacott M, Shumway-Cook A. Attention and the control of posture and gait: a review of an emerging area of research. *Gait Posture*. 2002;16(1):1-14.
3. Shumway-Cook A, Woollacott MH. Motor control: translating research into clinical practice 2th ed. Lippincott Williams & Wilkins; 2007.
4. Shumway-Cook A, Woollacott M. Attentional demands and postural control: the effect of sensory context. *J Gerontol A Bio Sci Med Sci*. 2000;55(1):M10.
5. Horak FB. Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? *Age Ageing*. 2006;35(suppl 2):ii7-ii11.

6. Sala SD, Baddeley A, Papagno C, Spinnler H. Dual-task paradigm: a means to examine the central executive. *Ann N Y Acad Sci*. 1995;769(1):161-72.
7. O'Shea S, Morris ME, Iansek R. Dual task interference during gait in people with Parkinson disease: effects of motor versus cognitive secondary tasks. *Phys Ther*. 2002;82(9):888-97.
8. Huang H-J, Mercer VS. Dual-task methodology: applications in studies of cognitive and motor performance in adults and children. *Pediatr Phys Ther*. 2001;13(3):133-40.
9. Yogev-Seligmann G, Hausdorff JM, Giladi N. The role of executive function and attention in gait. *Mov Disord*. 2008;23(3):329-42.
10. Pettersson AF, Olsson E, Wahlund L-O. Effect of divided attention on gait in subjects with and without cognitive impairment. *J Geriatr Psychiatry Neurol*. 2007;20(1):58-62.
11. Canning CG. The effect of directing attention during walking under dual-task conditions in Parkinson's disease. *Parkinsonism Relat Disord*. 2005;11(2):95-9.
12. Bowen A, Wenman R, Mickelborough J, Foster J, Hill E, Tallis R. Dual-task effects of talking while walking on velocity and balance following a stroke. *Age Ageing*. 2001;30(4):319-23.
13. McCulloch K. Attention and dual-task conditions: physical therapy implications for individuals with acquired brain injury. *J Neurol Phys Ther*. 2007;31(3):104-18.
14. Wu T, Liu J, Hallett M, Zheng Z, Chan P. Cerebellum and integration of neural networks in dual-task processing. *Neuroimage*. 2013;65:466-75.
15. Yang Y-R, Wang R-Y, Chen Y-C, Kao M-J. Dual-Task Exercise Improves Walking Ability in Chronic Stroke: A Randomized Controlled Trial. *Arch Phys Med Rehabil*. 2007;88.
16. Klockgether T, Lüdtke R, Kramer B, Abele M, Bürk K, Schöls L, et al. The natural history of degenerative ataxia: a retrospective study in 466 patients. *Brain*. 1998;121(4):589-600.
17. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state": a practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res*. 1975;12(3):189-98.
18. Trouillas P, Takayanagi T, Hallett M, Currier R, Subramony S, Wessel K, et al. International cooperative ataxia rating scale for pharmacological assessment of the cerebellar syndrome. *J Neurol Sci*. 1997;145(2):205-11.
19. Marchese R, Bove M, Abbruzzese G. Effect of cognitive and motor tasks on postural stability in Parkinson's disease: a posturographic study. *Mov Disord*. 2003;18(6):652-8.
20. Pellecchia GL. Dual-task training reduces impact of cognitive task on postural sway. *J Mot Behav*. 2005;37(3):239-46.
21. Morris M, Iansek R, Smithson F, Huxham F. Postural instability in Parkinson's disease: a comparison with and without a concurrent task. *Gait Posture*. 2000;12(3):205-16.
22. Galletly R, Brauer SG. Does the type of concurrent task affect preferred and cued gait in people with Parkinson's disease? *Aust J Physiother*. 2005;51(3):175-80.
23. Yang Y-R, Chen Y-C, Lee C-S, Cheng S-J, Wang R-Y. Dual-task-related gait changes in individuals with stroke. *Gait Posture*. 2007;25(2):185-90.
24. Yim-Chiplis PK, Talbot LA. Defining and measuring balance in adults. *Biol Res Nurs*. 2000;1(4):321-31.
25. Jonsson E, Seiger Å, Hirschfeld H. Postural steadiness and weight distribution during tandem stance in healthy young and elderly adults. *Clin Biomech*. 2005;20(2):202-8.
26. Berg K. Measuring balance in the elderly: preliminary development of an instrument. *Physiother Can*. 1989;41(6):304-11.
27. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc*. 1991;39(2):142-8.
28. Whitney SL, Marchetti GF, Morris LO, Sparto PJ. The reliability and validity of the Four Square Step Test for people with balance deficits secondary to a vestibular disorder. *Arch Phys Med Rehabil*. 2007;88(1):99-104.
29. Abernethy B. Dual-task methodology and motor skills research: some applications and methodological constraints. *J Human Mov Stud*. 1988;14(3):101-32.
30. Dite W, Temple VA. A clinical test of stepping and change of direction to identify multiple falling older adults. *Arch Phys Med Rehabil*. 2002;83(11):1566-71.
31. Pajala S, Era P, Koskenvuo M, Kaprio J, Törmäkangas T, Rantanen T. Force platform balance measures as predictors of indoor and outdoor falls in community-dwelling women aged 63-76 years. *J Gerontol A Biol Sci Med Sci*. 2008;63(2):171-8.
32. Lajoie Y, Teasdale N, Bard C, Fleury M. Attentional demands for static and dynamic equilibrium. *Exp Brain Res*. 1993;97(1):139-44.
33. Teasdale N, Bard C, LaRue J, Fleury M. On the cognitive penetrability of posture control. *Exp Aging Res*. 1993;19(1):1-13.
34. Shumway-Cook A, Woollacott M, Kerns KA, Baldwin M. The effects of two types of cognitive tasks on postural stability in older adults with and without a history of falls. *The J Gerontol A Biol Sci Med Sci*. 1997;52(4):M232-M40.