Medical Hypotheses 126 (2019) 149–153

Contents lists available at ScienceDirect

Medical Hypotheses

journal homepage: www.elsevier.com/locate/mehy

Does integrated cognitive and balance (dual-task) training improve balance and reduce falls risk in individuals with cerebellar ataxia?

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ARTICLE INFO

Keywords:
Dual-task
Cerebellar ataxia
Balance training
Feasibility
Fall prevention and economic evaluation

ABSTRACT

Frequent falls in people with cerebellar ataxia (CA) is a significant problem Therefore, an intervention that could improve balance and reduce the number of falls is of paramount importance from the patients' perspective. Combining cognitive training with physical training to improve balance is a new approach for reducing the risk of falls in patient populations who are at risk for falls. To determine if adding structured cognitive demands to conventional balance and coordination training we designed the Cognitive-coupled Intensive Balance Training (CIBT) program. We found that the more intensive and focused CIBT intervention reduced dual-task cost, improved balance, and reduced the number of falls in a sample of individuals with CA. We hypothesize that (1) CIBT will improve balance and reduce falls; and (2) CIBT will be a cost-effective treatment option for improving balance and reduce falls. To test these hypotheses, we propose conducting a randomized controlled trial (RCT) with economic evaluation . This paper reports the findings of our study testing the feasibility of the CIBT program, rationale for testing our hypothesis and an overview of our future study design to test the effectiveness and cost-effectiveness of the CIBT program.

Background

Cerebellar ataxia (CA) includes health conditions affecting the cerebellum or its connections resulting in postural instability, gait disturbance, incoordination and cognitive impairment [1,2]. The prevalence of health conditions resulting in CA is estimated as 8.22/100,000 [3]. Spinocerebellar ataxia, a genetic disorder resulting in CA has a prevalence of 0.9–3.0/100,000 [4]. Poor balance and walking difficulties are hallmarks of diseases associated with CA [2,5]. Nearly 93% of people with CA report at least one fall over the past 12-month period [6]. Falls are very common in spinocerebellar ataxia type 3 [7]. An estimate of the annual excess cost of medical expenses per person with CA is € 18776 [8]. However, the cost of falls and falls related consequences are not well understood.

Therapeutic exercises are regarded as the first line intervention for individuals with CA [9]. Evidence-based guidelines in this population is limited [2]. Intact cerebellum, plays a key role in motor adaptation and regulation of balance [10]. However, people with CA show limited motor re-learning [11]. In contrast, some studies show evidence for motor re-learning with repeated practice [12,13]. Therefore, understanding the potential for motor re-learning is critical for designing therapeutic intervention in this population.

Dual task paradigm

A recent systematic review reported that dual tasking, that is, simultaneous performance of two tasks involving physical and cognitive tasks [14], predicts falls in people with cognitive impairment [15]. A recent study involving healthy adults found additional activation of the cerebellum during dual tasking and reported that the cerebellum is likely to control the neural networks responsible for such activities [16]. Dual tasking is found to deteriorate the performance of either or both tasks in people with neurological disorders [17,18]. This deficiency in dual-task performance relative to single-task performance is referred to as dual-task cost [19]. Training balance using dual-task is found to improve the ability to perform dual-task, that is, reduce the

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https://doi.org/10.1016/j.mehy.2019.03.001
Received 11 February 2019; Accepted 4 March 2019

Table 1
Mean difference between pre and post training using the CIBT program.

(n = 5)	D-Tc B	SOT (COMP)	LOS (MXE%)	BBS	SARA	EQ5D5L-VAS	Falls/month
Pre-test 1	66.6 ± 21.22%	71.8 ± 6.04	67.72 ± 12.91	41 ± 8.66	9.66 ± 3.01	78.33 (7.63)	5.6 ± 2.5
Post-test	52.22 ± 16.07	79.33 ± 10.78	75.41 ± 16.21	44.66 ± 6.42	9.83 ± 2.75	84.33 ± 9.01	3.6 ± 1.5
Effect size	0.76	0.86	0.52	0.48		0.51	0.91

* - significant at $p < 0.05$, D-TcB- dual-task cost of balance performance, SOT (COMP)- composite score of Sensory Organization Test, LOS(MxE%) – Maximal excursion of Limits of stability test, BBS- Berg Balance Scale, SARA- Scale for the assessment and rating of ataxia, EQ-5D-5L- EuroQol 5 dimension 5 level, .

dual-task cost among people with stroke [20], Parkinson's disease [21] and traumatic brain injury [22]. In individuals with CA, dual tasking is associated increased risk for falls [23] and gait disturbance [24]. Clinical studies on individuals with CA found that adding cognitive demand to a physical task increases the dual-task cost [23,25,26]. Difficulty in performing dual-tasks is due to the increase in demands in motor and cognitive resources.

Intensive balance and coordination training are found to be effective in reducing the symptoms of in-coordination, motor performance [27] and a short-term reduction in the number of falls [28]. *However, the available interventions do not address the deficiency during cognitive-motor interaction or dual-task cost in this population.* Dual-task training has been found to improve this interaction in people with neurological disorders [21,22,29,30]. Dual-task training is highly relevant to people with CA due to the presence of poor motor-cognitive interaction and the associated cognitive deficits [24]. Theory-driven claims are available for the use of dual-task training in CA [23,24]. However, to date, there is no study evaluating the effectiveness of dual-task training in people with CA [24].

Studies in context

Previously, we evaluated the effect of Tai-Chi training on improving balance and reducing the number of falls in people with neurological disorders [31]. Tai-Chi requires attention in order to engage in the correct sequence of movement and memory to remember the correct moves while practising [32]. This combination of physical activity with cognition (attention and memory) makes Tai-Chi a dual tasking exercise [32].

The systematic review with meta-analysis we conducted found no studies testing the effect of Tai-Chi for improving balance in CA [31]. Therefore, we conducted a feasibility study to evaluate the preliminary effects of Tai-Chi for improving balance and functional independence in CA; and test the feasibility and safety of the intervention for a future randomized controlled trial (RCT) [33]. The feasibility study [33] found beneficial effects of Tai-Chi for improving balance in people with CA.

We then conducted an RCT to compare the effectiveness of Tai-Chi compared with usual care control (no Tai-Chi) for improving balance and falls in people with CA. A trained Tai-Chi Master delivered the 8-form Tai Chi as group therapy for 60 min, once in 2 weeks for 12 weeks. Participants then complete unsupervised Tai Chi exercise for 60 min, twice a week for 6 months. After analysing 6-month follow-up data, we found significant improvement in balance measured with the Berg Balance Scale (BBS) and balance sub-component of the Scale for the Assessment and Rating of Ataxia (SARAbal) scale. However, balance measured with objective laboratory-based assessments (Limits of Stability-LOS and Sensory Organization Test- SOT) did not improve significantly relative to no treatment. In addition, the Tai-Chi did not reduce the number of falls at 6 months post-intervention, relative to no treatment [34].

Feasibility study findings

Given the lack of improvement in the number of falls in the clinical trial, we developed the Cognitive-coupled Balance Training (CIBT) for balance and falls prevention for people with CA to address the potential reasons for the null findings with respect to falls in the RCT we recently completed. We conducted a single group pre-post design (ethic reference ID: HSEARS20180807002) to test the feasibility and safety of the intervention with 5 participants with CA. Dual-task cost of balance performance was measured using the Timed up and go test with the formula: (d-TUG - Standard TUG)/Standard-TUG) × 100 [35]. Two objective laboratory-based assessments of balance were done using the composite score of the Sensory Organization Test (SOT) and maximal excursion of the Limits of Stability (SOT) test. Ataxia severity was assessed using the Scale for the assessment and rating of ataxia (SARA) and the number of falls were recorded. We found that the CIBT program was feasible, safe and potentially effective for people with CA. Table 1 summarises the key findings of the pilot study. The post-training assessment reported a reduction in the dual-task cost of balance performance, number of falls and an improvement in functional balance. The findings of the feasibility study are encouraging and support the scientific premise of our hypothesis.

Based on the findings from the feasibility study we propose to conduct a randomized controlled trial (RCT) to compare the treatment benefits of the dual-task (experimental: CIBT) training against the single-task (active control: conventional balance, coordination and cognition) training for reducing dual-task cost, improving balance and reduce the number of falls in participants with CA.

Our specific objectives will be to: (1) Evaluate the effectiveness of the dual-task (CIBT- experimental) training compared with single task (conventional intensive balance, coordination and cognitive- active control) training on functional balance and number of falls, and (2) Compare the cost-effectiveness of the dual-task and single-task training for preventing falls.

Scientific premise for testing proposed hypotheses

Hypothesis 1*:* Poor attention allocation to balance during dual tasking is a strong predictor of subsequent falls [36]. Improvements in balance and gait facilitate gait automaticity, which in turn allows more attention allocation to the cognitive task resulting in the reduction of risk [36] and fear of falls [37] among the elderly. Therefore, we hypothesise a greater reduction in the number of falls following dual-task in comparison to single-task training.

Hypothesis 2*:* Results of our pilot study demonstrate that the dual-task training (CIBT) program has the potential to reduce the number of falls ($d = 0.91$) in people with CA. Therefore we hypothesise a reduction in the number of falls will result in the reduction in healthcare utility making the intervention (dual-task training) cost-effective for falls prevention.

Study protocol

An assessor and statistician blinded two-arm parallel group, RCT comparing dual-task (CIBT) to single-task (conventional balance, coordination and cognitive) training will be conducted with 44 participants with CA. Eligible participants will be randomized to study groups and allocation will be concealed. Participants will be randomized to one

Table 2
Primary and secondary outcome measures.

Outcome measures	*Domains assessed and interpretation of results*	*Measurement timeline*			
		T1 (0w)	T2 (6w)	T3 (10w)	T4 (34w)
Baseline characteristics	Age, age at disease onset, gender, employment status, disease diagnosis, disease duration, signs of cerebellar dysfunction (gait ataxia, dysmetria, speech disturbance and nystagmus), use of walking aid (users, non-users) and medication history	✓			
Primary outcome measures					
Dual-task cost of balance and cognitive performance	Reports the deficiency of balance and cognition in dual-task performance relative to single-task performance will be reported in percentage. Lower the percentage obtained better the dual tasking performance of balance and cognition.		✓	✓	✓
Secondary outcome measures					
SOT	Will be assessed using the Bertec ® system. Ability to stand unsupported in conditions challenging the visual, vestibular and somato-sensory inputs will be assessed [42,43]. We will assess (1) equilibrium score using the center of gravity (COG) sway of each condition, (2) composite equilibrium score and (3) sensory analysis ratio.		✓	✓	✓
Dual-task SOT (d-SOT)	The SOT variables will be repeated adding a cognitive task to assess static balance during dual tasking. Participants will be instructed to count backwards for a random number. Lower score indicating poor performance of sensory interaction during dual-task.		✓	✓	✓
Limits of stability (LOS)	Will be assessed using the Bertec ® system. The LOS assesses the ability to shift weight in 8 difference directions. We will assess Reaction time (RT) and Maximal Excursion (MxE)		✓	✓	✓
Number of falls	Number of falls will be obtained used digital diary. We operationally define a fall as an event when the person ends up on the ground or other surfaces due to a trip or any other unintentional activity, and a near fall as an unexpected loss of balance that did not result in complete loss of upright standing.		✓	✓	✓
Montreal Cognitive Assessment (MoCA),	MoCA estimates memory, executive function, attention, language, abstraction, naming, delayed recall and orientation [38]. This brief tool scores cognitive function out of 30, with a higher score equating to better function [38].		✓	✓	✓
Scale for the Assessment & Rating of Ataxia (SARA)	Is a measure for rating severity of ataxia [44]. SARA has eight sub-components with a total score of 40, higher scores indicating greater severity of symptoms due to ataxia. It is reported to have good reliability, validity and responsiveness in CA. [40,41,44]	✓	✓	✓	✓
Balance sub-components of SARA (SARAbal)	Gait, walking and standing sub-components of the SARA are relevant to balance assessment andi s called the SARAbal. [40,41] SARAbal is scored out of 18 with higher the score obtained greater the severity of balance impairment.		✓	✓	✓
Berg Balance Scale (BBS)	Is a measure of dynamic balance scored out of 56, higher scores indicating better balance. The BBS is found reliable and validity in people with CA. [40,41]		✓	✓	✓
EuroQol-5-dimension-5-level (EQ-5D-5L).	Health status will be assessed using the EuroQol-5-dimension-5-level (EQ-5D-5L). It is a standardised measure of health status used for economic appraisal. [45]		✓	✓	✓
Medical expense	Is an ongoing assessment from the onset of intervention.		✓	✓	✓

SOT – Sensory Organization Test, d-SOT – dual-task Sensory Organization test.

of the two groups: Group 1: Dual-task (CIBT) training; and Group 2: Single-task active control (conventional balance, coordination and cognition) training.

Sample size calculation

We will enrol 44 participants (22 in each group), allowing 10% attrition rate. Using the data from our pilot study, for using dual-task cost of balance performance as a primary outcome measure, assuming 90% power, 5% type I error and allowing 10% dropout, the required sample size is 44 (22 in each group).

Participants

Study inclusion criteria include: (1) men and women in the age group of 18–60 years; (2) with a confirmed diagnosis of CA (of any type); (3) able to walk independently with or without walking assistive aids. Study exclusion criteria will be: (1) previous history of other neurological diseases (such as Parkinson's disease, stroke, or polyneuropathies) or musculoskeletal problems severely impairing balance, gait or motor performance; (2) able to walk only with handheld support (3) severe visual impairment preventing from exercise participation and (4) severe cognitive impairment with scores < 16 on the Montreal Cognitive Assessment (MoCA) scale [38].

Randomization and blinding

A person not involved in the study will randomize participants to study groups in permuted blocks through computer-generated random numbers list. One HK registered physiotherapist (RA1) will be recruited to provide intervention to participants. Assessments will be performed blinded to the treatment conditions. Statistical analysis will be performed blinded to the treatment condition by the statistician.

Procedure

First baseline assessment (T1) will be completed after written informed consent. Participants will then be requested to return after 6 weeks for a second baseline assessment (T2). Study intervention will not be provided during this six-week period. Consistent with a previous study [27], in order to allow a prospective number of falls assessment and progress in disease severity, we plan to conduct two baseline assessments at a 6-week interval. Post-intervention assessment will be performed after 4 weeks of intervention (T3) and a follow-up assessment will be performed after 6 months (T4).

Intervention

Treatment will be initiated for both the groups after the second baseline assessment. The exercise intervention will continue for 7 months, beginning with supervised training at PolyU for 1-month. Intervention for both groups will be for 60 min, 3 times a week for 4-weeks. At the end of the training phase at PolyU, participants will be asked to complete an unsupervised home exercise programme over the next 6 months, based on the trial intervention.

Group 1: Dual-task (CIBT- experimental) group participants will receive 10 min of warm up, 40 min of CIBT training and 10 min of cool down exercises. CIBT program includes performing four types of cognitive tasks during sit to stand, standing with feet apart, one leg, tandem standing, multidirectional reaching, stair climbing and walking (10 m) tasks. The four cognitive tasks will include: counting backwards by subtracting 4 numbers (for mental tracking), naming fruits, vegetables, or animals (for working memory), auditory cues for performing activities, example, perform heel raise when you hear the alphabet H (for improving attention and auditory discrimination), short story telling (for verbal fluency). In addition, falls prevention strategies will be taught. These exercises are consistent with previous studies on dual-task training for people with mild cognitive impairment [39].

Group 2: Single-task (conventional balance, coordination and cognitive training- active control) group participants will receive 10 min of warm-up, 20 min of conventional balance and coordination exercises that are in accordance to previously published literature [27], 20 min of cognitive training as single-task (same 4 tasks provided for the CIBT) and 10 min of cool down. In addition, falls prevention strategies will also be taught.

Outcome measure

Table 2 reports the summary of the proposed outcome measures, domains tested, interpretation and the assessment timeline.

Participants will be instructed to complete the digital diary once every week. A printed version of the cost and falls diary will be provided to participants who do not have regular access to the internet. Postage-paid envelopes will be added to each printed cost diary to obtain a better response rate and participants will be instructed to post the completed forms once a month.

Statistical analyses

Hypothesis 1:. *Changes in primary and secondary outcome measure between mean baseline (T2), post-intervention (T3) and follow-up (T4) across the intervention groups will be evaluated using an Analysis of covariance (ANCOVA) at 95% confidence interval. The baseline score will be adjusted for disease duration, ataxia severity and assistive walking device usage (co-variates). Time points 2 and 3 will be compared to establish immediate treatment effects and T2 and T4 will report retention of treatment effect.*

Hypothesis 2:. *The EQ-5D-5L response will be converted into utility scores which will be used to estimate the quality-adjusted life-year (QALY) gain or loss over the follow-up period. The mean QALY gain or loss will be calculated for each group at six months. In addition, the mean incremental QALY gain will be estimated for the intervention groups. The incremental cost-effectiveness ratio (ICER) will be calculated using the mean incremental cost and mean incremental effect by substituting with the formula: $ICER = \Delta C/\Delta E$, where E is the gain in QALY and C is the cost. The cost-effectiveness of the intervention groups will be geographically represented using the cost-effectiveness plane (CE). The threshold (λ) for cost-effectiveness or the amount of money the country is willing to pay to gain one unit of effect (QALY) will be calculated.*

Consequences of hypotheses

If the hypotheses we made were found true, the findings of this cutting-edge research are important to the clinicians, researchers, policy-makers and people with CA. This study finding will have important clinical implications by clarifying if adding a cognitive demand to routine balance and coordination training will result in additional benefits on improving balance and reducing falls in comparison with usual care in people with CA.

Conclusion

People with CA also present with varying degrees of cognitive impairments making it difficult for them to perform dual-tasks in daily activities. Dual tasking has been found to deteriorate the performance of either or both tasks in people with CA. The use of dual-task training to reduce dual-task cost has been found to be effective in stroke, parkinson's disease and the elderly population. The use of dual-task training to improve balance and reduce the number of falls for people with CA is novel and worthwhile testing.

Conflict of interest

The team of authors report no conflict of interest.

Acknowledgments

The feasibility study was funded by the Hong Kong Spinocerebellar Ataxia Association (HKSCAA). Funding reference: H-ZH2W. The research team acknowledges all our participants and our research assistants, Mr Kwan Wills and Mr Umar Bello Muhammad for thier assistance and support.

References:

[1] Maja Steinlin KW. Cerebellum and cognition. In: MantoGruol D, Chmahmann JD, Koibuchi N, Rossi F, editors. Hnadbook of teh cerebellum and cerebellar disorders. Dordrecht: Springer Sciecne + Business Media; 2013.
[2] Winser SJ, Smith CM, Hale LA, et al. Systematic review of the psychometric properties of balance measures for cerebellar ataxia. Clin Rehabil 2015;29(1):69–79.
[3] Joo B-E, Lee C-N, Park K-W. Prevalence rate and functional status of cerebellar ataxia in Korea. Cerebellum 2012;11(3):733–8.
[4] Marsden J, Harris C. Cerebellar ataxia: pathophysiology and rehabilitation. Clin Rehabil 2011;25(3):195–216.
[5] Winser SJ, Shubert MC, Chan AY, et al. Can pre-screening vestibulocerebellar involvement followed by targeted training improve the outcomes of balance in cerebellar ataxia? Med Hypotheses 2018.
[6] van de Warrenburg BP, Steijns JA, Munneke M, et al. Falls in degenerative cerebellar ataxias. Mov Disord 2005;20(4):497–500.
[7] Fonteyn EM, Schmitz-Hübsch T, Verstappen CC, et al. Falls in spinocerebellar ataxias: results of the EuroSCA Fall Study. Cerebellum 2010;9(2):232–9.
[8] López-Bastida J, Perestelo-Pérez L, Montón-álvarez F, et al. Social economic costs and health-related quality of life in patients with degenerative cerebellar ataxia in Spain. Mov Disord 2008;23(2):212–7.
[9] Fonteyn EM, Keus SH, Verstappen CC, et al. The effectiveness of allied health care in patients with ataxia: a systematic review. J Neurol 2014;261(2):251–8.
[10] Fonteyn EM, Heeren A, Engels J-JC, et al. Gait adaptability training improves obstacle avoidance and dynamic stability in patients with cerebellar degeneration. Gait Posture 2014;40(1):247–51.
[11] Smith MA, Shadmehr R. Intact ability to learn internal models of arm dynamics in Huntington's disease but not cerebellar degeneration. J Neurophysiol 2005;93(5):2809–21.
[12] Ioffe M, Ustinova K, Chernikova L, et al. Supervised learning of postural tasks in patients with poststroke hemiparesis, Parkinson’s disease or cerebellar ataxia. Exp Brain Res 2006;168(3):384–94.
[13] Schwabe A, Drepper J, Maschke M, et al. The role of the human cerebellum in short- and long-term habituation of postural responses. Gait Posture 2004;19(1):16–23.
[14] Lauenroth A, Ioannidis AE, Teichmann B. Influence of combined physical and cognitive training on cognition: a systematic review. BMC Geriatrics 2016;16(1):141.
[15] Muir-Hunter S, Wittwer J. Dual-task testing to predict falls in community-dwelling older adults: a systematic review. Physiotherapy 2016;102(1):29–40.
[16] Wu T, Liu J, Hallett M, et al. Cerebellum and integration of neural networks in dual-task processing. Neuroimage 2013;65:466–75.
[17] Yogev G, Giladi N, Peretz C, et al. Dual tasking, gait rhythmicity, and Parkinson's disease: which aspects of gait are attention demanding? Eur J Neurosci 2005;22(5):1248–56.
[18] Sheridan PL, Solomont J, Kowall N, et al. Influence of executive function on locomotor function: divided attention increases gait variability in Alzheimer's disease. J Am Geriatr Soc 2003;51(11):1633–7.
[19] Strobach T, Torsten S. Mechanisms of practice-related reductions of dual-task interference with simple tasks: data and theory. Adv Cognit Psychol 2017;13(1):28.
[20] He Y, Yang L, Zhou J, et al. Dual-task training effects on motor and cognitive functional abilities in individuals with stroke: a systematic review. Clin Rehabil 2018. 0269215518758482.
[21] Strouwen C, Molenaar EA, Münks L, et al. Training dual tasks together or apart in Parkinson's disease: results from the DUALITY trial. Mov Disord 2017;32(8):1201–10.
[22] Evans JJ, Greenfield E, Wilson BA, et al. Walking and talking therapy: improving cognitive–motor dual-tasking in neurological illness. J Int Neuropsychol Soc 2009;15(1):112–20.
[23] Jacobi H, Alfes J, Minnerop M, et al. Dual task effect on postural control in patients with degenerative cerebellar disorders. Cerebellum Ataxias 2015;2(1):6.
[24] Ilg W, Timmann D. Gait ataxia—specific cerebellar influences and their rehabilitation. Mov Disord 2013;28(11):1566–75.
[25] Maciel MA, Silva ACSM, Cyrillo FN, et al. Impact of dual task on Parkinson's disease, stroke and ataxia patients' gait: a comparative analysis. Psicol: Reflexão e Crít 2014;27(2):351–7.
[26] Kraan CM, Hocking DR, Georgiou-Karistianis N, et al. Cognitive-motor interference during postural control indicates at-risk cerebellar profiles in females with the FMR1 premutation. Behav Brain Res 2013;253:329–36.
[27] Ilg W, Synofzik M, Brötz D, et al. Intensive coordinative training improves motor performance in degenerative cerebellar disease. Neurology 2009;73(22):1823–30.
[28] Miyai I, Ito M, Hattori N, et al. Cerebellar ataxia rehabilitation trial in degenerative cerebellar diseases. Neurorehabil Neural Repair 2012;26(5):515–22.
[29] Yang Y-R, Wang R-Y, Chen Y-C, et al. Dual-task exercise improves walking ability in chronic stroke: a randomized controlled trial. Arch Phys Med Rehabil 2007;88(10):1236–40.
[30] Mendel T, Barbosa WO, Sasaki AC. Dual task training as a therapeutic strategy in neurologic physical therapy: a literature review. CEP 2015;41810:480.
[31] Winser SJ, Tsang WW, Krishnamurthy K, et al. Does Tai Chi improve balance and reduce falls incidence in neurological disorders? A systematic review and meta-analysis 0269215518773442 Clin Rehabil2018.
[32] Chan W-N, Tsang WW-N. Effect of Tai Chi training on dual-tasking performance that involves stepping down among stroke survivors: a pilot study. Evidence-Based Complementary Altern Med 2017;2017.
[33] Winser Stanley KP, Marco Pang, Catherine Smith, William Tsang. Potential benefits and safety of Tai Chi for balance and functional independence in people with cerebellar ataxia. Journal of Alternative and Complementary Medicine 2018. in press.
[34] Stanley Winser WT, Anne Susan Whitney Chan Yin Yan, Kannan Priya. Cost effectiveness of Tai Chi for improving balance and falls prevention in cerebellar ataxia: an economic evaluation alongside a randomized controlled trial Singapore International Physiotherapy Conference (SIPC 2018). Singapore: Singapore Physiotherapy Association; 2018. p. 34–5.
[35] Abernethy B. Dual-task methodology and motor skills research: some applications and methodological constraints. J Hum Mov Stud 1988;14(3):101–32.
[36] Hall CD, Heusel-Gillig L. Balance rehabilitation and dual-task ability in older adults. J Clin Gerontol Geriatrics 2010;1(1):22–6.
[37] Wollesen B, Mattes K, Schulz S, et al. Effects of dual-task management and resistance training on gait performance in older individuals: a randomized controlled trial. Front Aging Neurosci 2017;9:415.
[38] Smith T, Gildeh N, Holmes C. The Montreal Cognitive Assessment: validity and utility in a memory clinic setting. Can J Psychiatry 2007;52(5):329–32.
[39] Nascimbeni A, Caruso S, Salatino A, et al. Dual task-related gait changes in patients with mild cognitive impairment. Funct Neurol 2015;30(1):59.
[40] Winser S, Smith CM, Hale LA, et al. Psychometric properties of a core set of measures of balance for people with cerebellar ataxia secondary to multiple sclerosis. Arch Phys Med Rehabil 2017;98(2):270–6.
[41] Tsang W, Fong S, Ng S. Dynamic sitting balance control tests in stroke survivors: a study of reliability and validity. Int J Stroke 2013.
[42] Peterka RJ, Black FO. Age-related changes in human posture control: sensory organization tests. J Vestib Res 1990;1(1):73–85.
[43] Kawahara Y, Ikeda Y, Deguchi K, et al. Simultaneous assessment of cognitive and affective functions in multiple system atrophy and cortical cerebellar atrophy in relation to computerized touch-panel screening tests. J Neurol Sci 2015;351(1–2):24–30.
[44] Schmitz-Hübsch T, Du Montcel ST, Baliko L, et al. Scale for the assessment and rating of ataxia Development of a new clinical scale. Neurology 2006;66(11):1717–20.
[45] EuroQol G. EuroQol–a new facility for the measurement of health-related quality of life. Health Policy (Amsterdam, Netherlands) 1990;16(3):199.