Blood pressure and heart rate adjustment following acute Frenkel's ambulatory exercise in chronic hemiparetics stroke survivors: a comparative study

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Abstract:
Background:
Frenkel's ambulatory activity has been routinely employed by physiotherapists for rehabilitation of gait coordination, however, its immediate influence on blood pressure and heart rate has not been investigated.
Objective
To investigate the acute effect of Frenkel's ambulatory activity on blood pressure and heart rate of chronic hemiparetic stroke survivors.
Method
Using a comparative study design, 60 chronic hemiparetic stroke survivors of varying onset of stroke, ≤6, >6-11 and ≥12 months were subjected to a 2-minute Frenkel's ambulatory activity on marked footsteps (from standard adult described footsteps). Participants were assessed for both blood pressure and heart rate before and after the Frenkel's ambulatory activity.
Results
Blood pressure and heart rate significantly increased ($p<0.05$) following Frenkel's ambulatory activity in all the 3 categories of stroke onset above baseline. However, there was no significant difference ($p>0.05$) across the onsets in both blood pressure and heart rate responses.
Conclusion
The outcome of this study indicated that Frenkel's ambulatory activity has the propensity to increase blood pressure and heart rate of hemiparetic stroke survivors irrespective of the onset of stroke. We recommend a pre, within and post-activity monitoring of stroke survivors while subjecting them to Frenkel's ambulatory activity.
Keys words: cardiovascular, ambulatory activity, stroke
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Introduction

Gait is an organized motor activity essential for the performance of activities of daily living. Gait activity in humans is made possible through a sensory- motor control systems of complex integration. The exact cortical, subcortical, and spinal control mechanisms of gait remain unclear[1]. Stroke interferes with the specialized organization of these neural control systems extending the period of ambulatory impairment. These results in physical inactivity and deconditioning which accelerate declines in neuromuscular function and cardiorespiratory endurance, increase the risk for cardiovascular disease and increase disability[2].

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Impaired walking ability is a hallmark of the residual deficit following stroke. At the early stage of stroke, the paresis of the lower-extremity secondary to impairment of muscle activation decreases the likely effort to propel the limb to swing and the ability to use the limbs as a base of support during stance[3,4]. As time from stroke increases beyond the early post-stroke period, motor control, muscle strength (force-generating capacity), and walking ability gradually improve[5]. Persistent gait inefficiency might still be present as a result of residual impairment and development of other secondary impairments[6,7]. Coupled with paresis, stroke disrupts selective voluntary control and can leave the

patient with primitive patterns of muscle action and spasticity[8]. Additionally, disuse muscular atrophy might compound the initial neurological deficit, and such muscle weakness could prevail for longer period irrespective of the functional recovery attained during the acute phase[9]. The resulting effect of these impairments on walking is reduced speed and endurance, poor balance and a seemingly, asymmetry during gait.

Stroke does not often occur alone as, patients with stroke present with other forms of medical conditions[10]. These conditions could pre-date the stroke or post-stroke (as complications). About 175% of stroke survivors have been reported to present with cardiac disease[10]. Physical activity places greater energy demand on cardiovascular system of hemiplegic patients than apparently healthy individuals. Stroke survivors with pre-existing or post-stroke cardiac disease might be at increased risk for exertion related cardiac complications[10]. Such complications, might delay or inhibit participation in a therapeutic exercise program, complicate the rehabilitation and/or extend long-term post-stroke course of care. The overall effect is, limiting the ability of the patient to perform functional activities independently[11-14].

Frenkel's exercise is an aerobic exercise that consists of a series of carefully planned activities, aimed at making the patient employ what is left to him/her of muscle sense, in order to prevent further decline of the muscle sense or even effect an improvement[15]. The exercise was primarily developed to treat sensory ataxic patients having complaints of loss of impulses and lack of voluntary control mechanism[15]. Subsequently, the exercise was adopted in the rehabilitation of a number of conditions with impaired gait, balance and coordination, including stroke. Gait disorders in stroke could be compounded by sensory loss apart from the motor impairments[16]. The sensory impairments could include proprioceptive loss leading to inability to be aware of position of the limbs in space and thus, where to place them[17]. The concept of Frenkel's exercise is to compensate for that loss with the visual system which can update the central nervous system about the position of the limbs in space and their direction of movement, thereby, contributing to balance and improving gait pattern. Detailed administrative protocol of the exercise has been explained elsewhere[15,18]. The ambulatory part of the exercise is the most advanced stage of the exercise and it is characterized by a well-coordinated exercise, with patients required to place their feet in marked footprints as they advance in walking. This activity requires a lot of concentration, coordination and endurance and may serve as a threat to the cardiovascular system, especially in hemiparetic stroke survivors. This is because paretic gait is known to be associated with a high-energy demand compared with the non-paretic[19,20], and stroke subjects' show poor endurance[19,21]. Frenkel's exercise has become a popular exercise protocol among therapists, administered mainly for gait correction and coordination. However, there has been no documented literature on the potential cardiovascular adjustments following Frenkel's ambulatory exercise. Our study investigated the effect of Frenkel's ambulatory activity on selected cardiovascular parameters (specifically, blood pressure and heart rate) with an aim to identify to what extent these parameters are influenced by the acute effect of the activity.

Methods

Participants

Sixty male and female chronic hemiparetic stroke survivors were recruited to participate in this comparative study. Participants were all recruited from the outpatient physiotherapy clinic of Aminu Kano Teaching Hospital,Kano. Recruitment of participants was specifically targeted at engaging 3-categories of hemiparetic stroke survivors based on their time since stroke (or stroke onset).

These categories are: ≤ 6-months (group A),>6-11 (group B), and ≥12 (group C) with each group having a total of 20 participants. Recruited participants were found to conform to study inclusion criteria which include: a) A history of cardio-vascular accident (CVA) of at least 3-months of onset. b) Unimpaired cognition and having positive motivation. c) Ability to walk a distance of 10m (walking aids are permitted, but not the help of another person). d) Ability to stand from sitting without help and walk a minimum of 10m independently prior to CVA. e) Signing a written informed consent. Similarly, participants were excluded if they present: 1) have had some sort of Frenkel's activity earlier. 2) Receptive aphasia. 3) Medical instability (e.g. uncontrolled blood pressure, arrhythmias, and unstable cardiovascular characteristics). 4) Participants with visual impairments such as blurred vision, long or short sightedness. 5) A history of fracture or significant orthopaedic surgical procedure in the upper and/or lower limb interfering with patient's functional ability to walk prior to or post-CVA. 6) Other medical conditions severe enough to impair functional activities (e.g. walking).

Procedure

This study is a comparative observational study of the pre/post test influence of Frenkel's ambulatory activity on heart rate and blood pressure in hemiparetic stroke survivors undergoing rehabilitation. The study was conducted in the gymnasium of the Department of Physiotherapy, Aminu Kano Teaching Hospital (AKTH).The study was approved by the ethics committee of AKTH.

Prior to the commencement of the study participants' physical characteristics including: body mass (in each study group) was measured and recorded to the nearest 0.1kg and stature to the nearest 0.1m and body mass index (BMI), defined as body mass in kilogram divided by stature in meter squared (kg/m-2). All physical characteristics measurements were performed according to the International Society for the Advancement of Kinanthropometry guidelines[22] (all these were measured once, solely to describe participants features). The physiological parameters including blood pressure and heart rate were measured at rest and post-Frenkel's ambulatory activity. The resting blood pressure and heart rate were measured with the participants seated comfortably at least 10 minutes prior to measurement using automated blood pressure monitor (Model: Omron BP710). The means of two consecutive readings of both blood pressure and heart rate were recorded, similarly, the procedure was performed immediately after completion of a single bout of the minute walk of Frenkel's ambulatory exercise; no room was permitted for a rest, so as to capture the immediate (acute) cardiovascular adjustments (in terms of blood pressure and heart rate).

Administration of Frenkel's ambulatory exercise

A 2-minute walk in a coordinated fashion guided by marked footprints was performed by each participant (monitored individually). This is chosen based on the characteristic of the study population[23]. The 2-minute walk test was specifically administered to determine the immediate effect of the Frenkel's ambulatory activity. The ambulatory activity was performed on a flat concrete floor, with marked footprints of 9cm step width and seven degrees foot angle, these measurements have been reported as the average gait characteristic for adults[4].

To commence the activity, participants were instructed to watch the movement they perform and to give full attention to the activity. They were asked to ensure that all movements are accurate and rhythmical. Each participant was asked to walk using his/her comfortable pace to ensure accuracy of placing each foot, on the marked footprints and to as much as possible maintain even tempo throughout the activity. Participants were encouraged from the beginning to the end of the exercise using phrases such as: a) you are doing well; b) you got it right; c) better foot placement and d) maintain the tempo. Activity was performed on separate days for each group of participants (i.e. ≤6 months as A, >6-11 as B, ≥12 as C).

Data analysis

Data were analysed using descriptive statistics (mean±SD), dependent sample t-test and one-way ANOVA. Changes in blood pressure and heart rate were determined by analysing pre- and post- ambulatory values using dependent sample t-test and the percentage change was calculated using Microsoft excel. One-way ANOVA was used to determine differences in selected cardiovascular parameters in the three independent stroke onset categories. Analyses were conducted using Microsoft excel and SPSS (version 15.0) at a probability level of 0.05.

Results

A total of 60 stroke survivors participated in this study. Their mean age was 49.2±9.3 years and their mean BMI was 59.8±7.9 kgm-2. Thirty-eight (63.3%) of the participants were male, with thirty-two (53.3%) presenting with left-sided hemiplegia. However, the majority (90%) of the participants do not need walking aid, for ambulation (Table 1).

Table 1: Physical and disease characteristics of subjects

Variables	Combined (n=60)	Group A (n=20)	Group B (N=20)	Group C (n=20)	P-value
*Age, years	49.2 ± 9.3	48.3 ± 7.8	51.2 ± 11.0	48.2 ± 9.4	0.709†
*Body mass (kg)	59.8 ± 7.9	59.2 ± 9.6	60.0 ± 7.8	60.2 ± 6.9	0.959†
*Stature (m)	1.6 ± 0.1	1.7 ± 0.1	1.6 ± 0.1	1.7 ± 0.1	0.582†
*Body Mass Index (kgm-2)	21.9 ± 2.0	21.5 ± 3.2	22.4 ± 2.8	21.7 ± 3.1	0.788†
Gender (M/F)	38/22	14/6	12/8	12/8	
Side of hemiplegia (R/L)	28/32	12/8	10/10	10/10	
Walking aid (No/Yes)	54/6	18/2	16/4	20/0	

Group A, B & C= duration of onset (≤ 6, >6-11and ≥ 12 months respectively),* Values are in mean ± standard deviation, M/F=male to female count, R/F= right to left hemiplegia. †None of the comparisons of physical characteristics of participants were statistically significant at baseline in all the categories.

Pre and post blood pressure and heart responses

The differences in blood pressure and heart rate responses pre and post Frenkel's ambulatory activity was found to be significant for the both of the variables in all the 3 categories of stroke onset. In blood pressure both systolic and diastolic blood pressures demonstrated significant change (p<0.5) and this influence was also seen in the heart rate (Table 2).

Table 2: Changes in blood pressure and heart rate following Frenkel's ambulatory exercise

Variables	Test	Group A	%Δ	P-value	Group B	%Δ	P-value	Group C	%Δ	P-value
SBP (mmHg)	Pre	125.5±6.9			128.0± 7.1			125.0±9.1		
SBP (mmHg)	Post	141.1±4.6	12.4*	0.000	140.0±5.3	9.3*	0.000	139.6±5.0	11.7*	0.000
DBP (mmHg)	Pre	84.5±5.4			82.6±6.8			83.4±6.7		
DBP (mmHg)	Post	91.1±4.9	7.8*	0.000	89.2±6.0	8.0*	0.000	89.3±6.0	7.1*	0.000
HR (beats/min)	Pre	80.5±7.8			82.8±8.2			82.8±5.5		
HR(beats/min)	Post	113.3±7.0	40.7*	0.000	113.1±7.8	36.6*	0.000	112.6±10.9	36.0*	0.000

Group A, B & C= duration of onset (≤ 6, >6-11 & ≥ 12 months respectively),* SBP=systolic blood pressure, DBP=diastolic blood pressure,HR= heart rate, %Δ= mean percentage change, *result is significant critical t19=1.73 at 0.05α level

Cross-sectional variation in blood pressure and heart rate according to onset of stroke Participants were not found to differ significantly (P>0.05) in responses based on the duration of onset of stroke (groups A, B & C). The outcome of the study equally, indicated insignificant differences in blood pressure and heart rate after adjusting for age and hemiplegic side (P>0.05) across onset of stroke (Table 3)

Table 3: Differences in selected cardiovascular according to duration of stroke onset

Variables	Combined	Group A	Group B	Group C	F	*P*-value
SBP (mmHg)	14.1±5.7	15.6± 5.5	12.0±5.4	14.6±6.1	1.076	0.355ns
DBP(mmHg)	6.4±3.4	6.8±3.9	6.6±3.5	5.9±3.0	0.181	0.835ns
HR(beats/min)	30.9±9.1	32.8±10.1	30.3±9.2	29.8±8.8	0.294	0.748ns

Group A, B & C= duration of onset (≤ 6, > 6-11 & ≥ 12 months respectively), SBP= systolicblood pressure, DBP=diastolic blood pressure, HR= heart rate, $F_{2,12}$=3.89 at 0.05α level

Discussion

We conducted a comparative study to investigate the effect of acute Frenkel's ambulatory exercise on blood pressure and heart rate of chronic hemiparetic stroke survivors. The outcome of this study suggests that acute Frenkel's ambulatory exercise significantly increases both blood pressure and heart rate measures of hemiparetic stroke survivors within each onset categories. However, while these changes are observed within specific durations of stroke onset, responses were not found to differ significantly across the duration of stroke onset.

The outcome of this study indicating heightened blood pressure and heart rate following acute Frenkel's ambulatory exercise, cannot be considered a normal physiological change following dynamic aerobic exercise because of two important reasons. Firstly, ordinary physiological change following dynamic aerobic exercise increases is characterized by a rapid increase in cardiac output following increases in both stroke volume and heart rate, coupled with which is increasing systolic blood pressure (SBP) in a pattern very similar to that of cardiac output, without any obvious alteration in diastolic blood pressure (DBP).[23-25] Our study indicating a change in diastolic blood pressure negates the ordinary physiological variation seen in dynamic aerobic exercise under normal circumstances. Secondly, the implication of significant difference between pre and post intervention (in the variables) calls for a closer look into this activity (Frenkel's ambulatory exercise). This is because the physiological changes explained earlier are expressed with respect to normotensive population. The facts that stroke survivors have a known heightened risk of secondary cardiac complications and recurrent stroke, activities that task the cardiovascular system (such as the Frenkel's) must therefore be introduced with caution.

Several reasons can be advanced for the physiological responses seen in our sample. First, self- reported fatigue in stroke survivors is roughly a double higher compared to matched controls and is not related to time post stroke, severity, or lesion location[26]. This heightened level of fatigue could translate to an increased energy expenditure of hemiplegic gait which result from the inability to activate normal movement patterns[19]. The poor movement pattern has been linked with associated weakness, spasticity and abnormal central neural patterning of muscle activation[27]. Obviously, since Frenkel's ambulatory activity is geared towards correcting the movement pattern in stroke it might not therefore, be a surprise that its acute effect would alter physiological parameters significantly. Second, the gross physical deconditioning, age-associated decline in fitness and muscle mass, disproportionately large use of cardiovascular and metabolic capacity to produce ambulation[19,21,27] could all interfere with patients' physiological parameters to meet the challenge of this highly coordinated ambulatory activity when initially introduced.

A question might arise about why this difference when our sample are currently undergoing rehabilitation. An answer to this question has been provided by a previous study investigating exercise capacity in stroke survivors. The study monitored stroke survivors undergoing physiotherapy and occupational therapy [2] and 14 weeks post stroke. The study opined that therapy might be of insufficient intensity to produce a cardiorespiratory training impact[28]. It was discovered that on average in a physiotherapy session, 42% of the time was spent inactive in lying, 11% active in lying, 16% active in sitting and 31% active in standing and above all if it was present the aerobic component of a typical physiotherapy session lasted less than 3 minutes. Agreeably, with such a poor approach towards cardiorespiratory fitness being under therapy might not have put our participants in a good cardiorespiratory fitness to overcome the challenge posed by the Frenkel's ambulatory activity.

We compared the blood pressure and heart responses in the three categories of stroke survivors and found no significant difference in blood pressure and heart responses. This outcome might probably explain the lack of difference in fatigability and its consequence on cardiovascular response in stroke survivors which has been detailed in a study investigating the frequency and outcome of fatigue, its impact on functioning, and its relationship with depression in patients 3 to 13 months post-stroke. The outcome of which indicated that fatigue was not related to time post- stroke, stroke severity, or lesion location[27].

These results must be interpreted with caution owing to small sample size and the absence of a control group. We cannot rule out selection bias considering the array of recruitment criteria used in this study and this might surely create under representation of certain medical comorbidities. On overall our concern is that we may over emphasize the impact of this ambulatory activity on blood pressure and heart rate of hemiparetic stroke survivors. However, the key information remains that when introducing activity of this characteristic to stroke survivors there is the need to appreciate the cardiovascular status of the patients and to introduce such activity cautiously.

Conclusion

The acute effect of Frenkel's ambulatory exercise significantly increases blood pressure and heart rate responses of stroke survivors irrespective of onset time post-stroke. The clinical implication of this outcome is that poor monitoring of stroke survivors at the initial introduction to Frenkel's ambulatory activity can pose a threat to cardiovascular parameters, therefore, therapists need to identify properly the cardiovascular status of the patients prior to exposing to this activity. We recommend a more extensive study to further substantiate our findings.

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References

1. Swinnen SP: Inter-manual coordination: from behavioural principles to neural-network interactions. *Nature Review of Neuroscience,* 2002; 3: 348–359.
2. Luft AR, Macko RF, Forrester LW, Villagra F, Ivey F, Sorkin JD, Whitall J, Mccombe- Waller S, Katzel L, Goldberg AP, Hanley DF: Treadmill Exercise Activates Subcortical Neural Networks and Improves Walking After Stroke. *Stroke* 2008; 39(12): 3341–335.
3. De Quervain IA, Simon SR, Leurgans S, Pease WS, Mcallister D: Gait pattern in the early recovery period after stroke. *Journal Bone and Joint Surgery,* 1996; 78:1506–1514.
4. Perry J: Gait Analysis: Normal and Pathological Function. New York: McGraw-Hill, Inc. 1992.
5. Mulroy S, Gronley J, Weiss W, Newsam C, Perry J: Use of cluster analysis for gait pattern classification of patients in the early and late recovery phases following stroke. *Gait and Posture,* 2003; 18:114–125.
6. Kim CM, Eng JJ: The relationship of lower-extremity muscle torque to locomotor performance in people with stroke. *Physical Therapy,* 2003; 83:49–57.
7. Olney SJ, Richards CJ: Hemiparetic gait following stroke, part I: characteristics. *Gait and Posture,* 1996; 4:136–148.
8. Sullivan KJ, Brown DA, Klassen T, Mulroy S, Ge T, Azen SP, Winstein CJ: Effects of Task-Specific Locomotor and Strength Training in Adults Who Were Ambulatory After Stroke: Results of the STEPS Randomized Clinical Trial. *Physical Therapy,* 2007;87:1580-1602
9. Hachisuka K, Umezu Y, Ogata H. Disuse muscle atrophy of lower limbs in hemiplegic patients. Archives Physical Medicine and Rehabilitation, 1997; 78:13–18.
10. Gordon NF, Gulanick M, Costa F, Fletcher G, Franklin BA, Roth EJ, Shephard T. Physical Activity and Exercise Recommendations for Stroke Survivors : An American Heart Association Scientific Statement From the Council on Clinical Cardiology, Subcommittee on Exercise, Cardiac Rehabilitation, and Prevention; the Council on Cardiovascular Nursing; the Council on Nutrition, Physical Activity, and Metabolism; and the Stroke Council. *Circulation,* 2004; 109:2031-2041.
11. Richards CL, Olney S. Hemiparetic gait following stroke, part II: recovery and physical therapy. *Gait and Posture,* 1996; 4:149–162.
12. Roth EJ, Harvey RL. Rehabilitation of stroke syndromes. In: Braddom RL, ed. Physical Medicine and Rehabilitation. 2nd ed. *Philadelphia, Pa: WB Saunders;* 2000.
13. Dawes H, Collett J, Ramsbottom R, Howells K, Sackley C, Wade D. Measuring oxygen cost during level walking in individuals with acquired brain injury in the clinical setting . *Journal of Sports Science and Medicine,* 2004; 3: 76-82.
14. Narayanan SL: Text Book of Therapeutic Exercises. New Delhi, Jaypee Brothers medical publishers; 2005.

15. Zamparo P, Francescato MP, De Luca G, Lovati L, *Di Prampero PE:* The energy cost of level walking in patients with hemiplegia. *Scandinavian Journal of Medical Science and Sports,* 1995; 5: 348–352.
16. Sommerfield DK, Von Arbin M: The impact of somatosensory function on activity performance and length of hospital stay in geriatric patients with stroke. Clinical Rehabilitation, 2004; 18: 149–55.
17. Greenwood R, Barnes MP, Mcmillan Tm, Ward CD, editors. Handbook of Neurological Rehabilitation. London, Psychology Press, 2003.
18. Michael KM, Allen JK, Macko RF. Fatigue after stroke: Relationship to mobility, fitness, ambulatory activity, social support, and falls efficacy. Rehabilitation Nursing, 2006;31(5):210-217.
19. Waters RL, Mulroy S. The energy expenditure of normal and pathologic gait.*Gait and Posture,* 1999; 9: 207-231.
20. Carr J, Shepherd R. Enhancing Physical Activity and Brain Reorganization after StrokeNeurological Research International, 2011; doi:10.1155/2011/515938.
21. International Society for the Advancement of Kinanthropometry (ISAK). International standards for anthropometric assessment. Australia: 2001.
22. Lewis C, Shaw K: Benefits of the 2-Minute Walk Test. Physical Therapy and Rehabilitation Medicine, 2005; 16:6
23. Guyton AC, Hall JE: Textbook of Medical Physiology (11th ed.). Philadelphia, PA: Elsevier/Saunders; 2006.
24. Mcardle WD, Katch IF, Katch LV. Exercise Physiology: Energy, Nutrition and Human Performance. 5th Ed. Williams and Wilkins, Lippincott; 2001.
25. Plowman SA, Smith DL. Exercise Physiology for Health, Fitness, and Performance. 2nded. San Fransisco: Benjamin Cummings; 2008.
26. Ingles JL, Eskes GA, Phillips SJ: Fatigue after stroke. Archives of Physical Medicine and Rehabilitation, 1999; 80(2):173-178.
27. Macko RF, Smith GV, Dobrovolny CL, Sorkin JD, Goldberg AP, Silver KH: Treadmill training improves fitness reserve in chronic stroke patients. Archives of Physical Medicine and Rehabilitation, 2001; 82(7):879–884.
28. Mackay-Lyons MJ, Makrides L. Exercise capacity early after stroke. Archives of Physical Medicine and Rehabilitation, 2002, 83(12):1697-1702.