Journal of General Medicine

Research Article

Brief heat exposure and balance performance in older adults: a controlled trial

Beatriz Maria Trezza[1], Fábio Luiz Teixeira Gonçalves[2], Paulo Hilário Nascimento Saldiva[3], Wilson Jacob-Filho[1], Alexandre Leopold Busse[1]*

[1]Division of Geriatrics, Department of Internal Medicine, University of São Paulo Medical School, Av. Dr. Eneas de Carvalho Aguiar, 155, 8° Andar, Bloco 3, São Paulo, SP 05403-900, Brazil

[2]Institute of Astronomy, Geophysics, and Atmospheric Sciences, University of São Paulo, São Paulo, Brasil

[3]Department of Pathology, College of Medicine, University of São Paulo, São Paulo, SP, Brazil

Abstract

Nowadays two important processes are taking place simultaneously: global warming and population ageing. Ageing leads to changes in temperature control mechanisms that make elderly people more vulnerable to temperatures out of their comfort range. In addition to diminished thermoregulatory mechanisms, normal ageing is associated with declined postural control, which is an independent risk factor for falls in older adults. So, we have hypothesized that postural balance of older adults can be affected by high environmental temperatures. We carried out a controlled trial with 68 healthy older adults (mean age 73.3 years, 69 % female), each of whom had been assessed twice on the same day using Modified Clinical Tests of Sensory Interaction for Balance (mCTSIB) and the 100% Limits of Stability Test (LOS) to assess balance. They were conducted on the force platform Basic Balance Master System. All volunteers were residents of the Metropolitan Region of São Paulo (SPMA), a subtropical megacity. Repeated sessions were conducted with air temperatures set at 24 °C and 32 °C, in a balanced order. These temperatures were chosen in order to simulate extreme heat indoor SPMA climatology and a comfort temperature. We did not find significant differences for any individual measures or composite scores when comparing static balance assessed by mCTSIB performance under the two experimental temperatures. In the LOS test, except for the reaction time, all measurements were slightly better in the control session than in the heat session, but the difference was only statistically significant in the endpoint excursion (EPE) variable. In the composite score of LOS, a trend for difference was observed, with a p value of 0.10. Our results indicate that brief heat exposure may have detrimental effects on some aspects of balance in older adults.

Keywords: Environmental temperatures; Heat exposure; Postural balance; Ageing; Balance assessment

Introduction

Currently two important processes are taking place simultaneously: global warming and population ageing. Several studies have shown an increase in mortality associated to rises in ambient temperature; and advanced age is one of the most important factors [1-3] .

Ageing leads to changes in temperature control mechanisms that make elderly people more vulnerable to temperatures out of their comfort range. The temperature regulating mechanisms in response to heat such as sweating, increase in cardiac output and cutaneous vasodilation are progressively attenuated with ageing [4-7]. It has been shown that age negatively affects thermoregulation independently from other factors such as body fat and cardiorespiratory fitness [8].

In addition to diminished thermoregulatory mechanisms, normal ageing is associated with declined postural control, which is an independent risk factor for falls in older adults. Balance control is dependent upon sensory input, mainly vision, proprioception and vestibular function that reaches the central nervous system where it is processed and initiates a postural response. These sensory systems suffer impairment by ageing itself and age-related diseases [9]. Likewise, age-related musculoskeletal impairments such as reduced muscle mass and strength and limited range of motion in joints of the back and lower limbs affect balance [10].

Falls are a major health concern in the elderly and the incidence of them rises with age. Falling is multifactorial, and usually a combination of factors is responsible, both extrinsic (e.g., environmental and housing conditions) and intrinsic [11].

Objective measures of balance can be obtained by tests performed on a computerized force platform. It has been demonstrated that those force platform tests have good correlation to clinical tests and good test retest reliability [12-14].

Recently we have shown that heat stress may have detrimental effects on the cognitive functioning of older adults under high humidity environments [15]. So, we have hypothesized that postural high environmental temperatures could affect balance of older adults. Such effects could increase the risk of falls in elderly,

Submitted: 17 June 2020 | **Accepted:** 18 July, 2020 | **Published:** 22 July, 2020

***Corresponding author:** Alexandre Leopold Busse, Division of Geriatrics, Department of Internal Medicine, University of São Paulo Medical School, Av. Dr. Eneas de Carvalho Aguiar, 155, 8° Andar, Bloco 3, São Paulo, SP 05403-900, Brazil, Tel: 55(11)2661-6236; E-mail: alebusse@gmail.com

Citation: Trezza BM, Teixeira Gonçalves FL, Nascimento Saldiva PH, Jacob-Filho W, Busse AL (2020) Brief heat exposure and balance performance in older adults: a controlled trial. J Gen Med 4: 5.

representing a potentially relevant public health issue We carried out a controlled trial to evaluate whether an environment with an air temperature set at 32 °C would have detrimental effects on balance accessed by use of a force platform.

Moreover, we tried to identify factors that would explain variations in susceptibility to heat stress.

The focus of the controlled trial was based on subjects in the Sao Paulo Metropolitan Area (SPMA), the largest megacity in South America. According to Batista et al. [16], SPMA temperatures have been rising in the last decades and will have even raised more by the end of this century.

Materials and Methods

Subjects

We recruited a convenience sample of volunteers between January and August 2013 from community and clinical settings. The eligibility criteria were: age 60 years or older, ability to speak fluent Portuguese, have at least 4 years of formal education, and general good health, without neurological or psychiatric illness. All volunteers were also residents of the Metropolitan Region of São Paulo (SPMA), a subtropical megacity.

Subjects were screened for depression by the 15-item Geriatric Depression Scale (GDS-15) [17]; and for cognitive impairment by the Mini-Mental State Examination (MMSE) [18]. Participants who scored >5 on the GDS-15 or<24 on the MMSE were excluded. They were also submitted to the short physical performance battery (SPPB) and only those who scored 10 or more were included [19].

General procedure

Volunteers attended the laboratory on two occasions. In the first one, after an interview to collect socio-demographic data, the subjects underwent a training session. The training session occurred 7.9 (± 3.3) days before the study itself. In the second visit, always in the morning, participants completed the test protocol at the 2 temperatures. Two 30,000 BTU air conditioners, with automatic controls of temperature, but not of humidity., were used to acclimatized a room of 9.5ms^3. A control session with room temperature set to 24 °C and another set to 32 °C (heat session) were performed. These temperatures were chosen in order to simulate extreme heat indoor SPMA climatology and a thermal comfort temperature, based on the same climatology.

The order of the sessions, 24 °C (control) or 32 °C (heat), were defined through a computer generated allocation sequence in a 1: 1 ratio. Volunteers rested seated for 30 minutes in a waiting room at 24 °C before starting the first test in order to attenuate possible effects of the outdoor temperature. Between the first and second tests, there was also a 30-minute interval. The clothing volunteers used during the tests was not standardized; however, no change was allowed between the tests, so they were wearing the same outfit in both sessions.

The volunteers entered the room at the experimental temperature and started immediately the protocol with the hand grip strength (HGS) measurement and then the balance tests in the force platform (FP), as describedHand Grip Strength

HGS was measured by a handheld dynamometer, Jamar® (Sammons Preston Rolyan, Boilingbrook, IL, USA), in kilogram. The participants were instructed to sit down with their elbows flexed at an angle of 90° and the dynamometer held in the hand in a neutral position. Three attempts were performed with each hand, and the highest value was used for analysis

Balance Testing

The Modified Clinical Tests of Sensory Interaction for Balance (mCTSIB) and the 100% Limits of Stability Test (LOS) were used to assess balance. They were conducted on the force platform Basic Balance Master System (NeuroCom International Inc., Clackamas, OR, USA) instrument to extract quantitative data.

Modified Clinical Tests of Sensory Interaction for Balance

This test examines postural sway during 4 conditions: "standing on a firm surface with eyes open", "standing on a firm surface with eyes closed", "standing on a foam surface with eyes open", and "standing on a foam surface with eyes closed". Subjects stand on the force plate with their feet in a standard position. Each condition was tested 3 times with a short rest period between trials. The trial was stopped and repeated if the subjects opened their eyes in an eye-closed condition or lost balance and required manual assistance to prevent a fall. The order of completion of the 4 conditions was the same for all participants, as described above. In mCTSIB , we measured the mean center of gravity (COG) sway speed (which is measured in degrees per second over 30 s) for each of the 4 conditions. The lower the speed of COG, the more stable the subject is considered. Higher scores reflect increased sway and postural instability.

Limits of Stability

The LOS test quantifies the capacity to intentionally move the center of gravity (COG) to the stability limits without losing balance. Participants remain upright on the FP and receive the command to quickly move their COG toward eight targets spaced at 45 ° intervals represented on the computer monitor, one at a time. In the LOS test, the following are measured: reaction time (the time from the presentation of a start cue to the onset of the voluntary shifting of the participant's COG toward the target position), movement velocity (average speed of COG movement based on the 90 % of the distance, measured in degrees per second), end point excursion (EPE - percentage of the distance achieved toward a target on the initial movement), maximum excursion (the furthest distance traveled by the COG during the trial) and directional control (100 % being a straight line from the center of pressure to the intended target) " [20]. We used the composite score of each of these measurements, i.e. the average across all 8 directional targets.

Statistical analysis

Primary analyses were carried out by comparing parameters of balance performance under the two experimental temperatures. Due to the fact that some variables did not meet the requirements for normality (D'Agostino-Pearson test for Normal distribution), Wilcoxon test were performed to compare data between the two sessions.

In order to develop composite scores (one for CTSIB, one for LOS), raw data from the nine outcomes were transformed using the Box-Cox technique to improve distribution patterns. Z-scores were obtained using the mean of the total sample as the reference and composite scores were calculated by arithmetic means of the three outcomes from CTSIB and five from LOS. Composite scores were then scaled so that the average performance was assigned 100 and the standard deviation was established at 15. Tests in which lower scores indicate better performance had the signs reversed so that, in all the derived measures, higher scores indicate better performance.

An interaction analysis using repeated measures of analysis of variance (ANOVA) was carried out in order to check whether the effect of temperature on balance, assessed by the CTSIB and LOS composite scores, was modified by age, gender, frequency of physical activity. For the interaction analysis the variable age was stratified into two levels using the median value and frequency of physical activity using the value up to 3 times and more than 3 times per week.

Results

The total number of subjects who completed the tests at both temperatures was 69. One of these was excluded because was exposed in the heat protocol to a mean temperature considerably lower than the target (30.7 °C for a target of 32 °C).Therefore the sample analyzed consisted of 68 elderly, 69.1 % of whom were female, ranging from 61 to 88 years, mean age 73.3 years (±6.6). Information about exercising was obtained from 63 volunteers and most of the subjects declared to be physically active, i.e., exercised at least twice a week. 42.9% of volunteers reported practicing some exercise 4 or more times per week, 27.0 % between two and three, 9.5 % once a week, and only 20.6 % were completely sedentary.

Regarding the CTSIB, on foam with eyes closed condition, 5 volunteers failed to complete it and many (not counted) did so only after multiple attempts. We considered this a significant bias and we opted to exclude it from the analyses. Regarding LOS test, one volunteer was unable to move the center of gravity backwards; so, only the data from 67 participants were analyzed.

The force evaluated by the HG was not different in the two sessions. In the same way, we have not found significant differences for any individual measures or composite scores when comparing static balance assessed by mCTSIB performance under the two experimental. In the LOS test, except for the reaction time, all measurements were slightly better in the control session than in the heat session, but the difference was only statistically significant in the Endpoint Excursion (EPE) variable. In the composite score of LOS, a trend for difference was observed, with a p value of 0.10 (Table 1).

In interaction analyses, the effects of heat exposure on balance performance, assessed by CTSIB and LOS composite scores, were not modified by age, gender and frequency of physical activity.

Discussion/Conclusion

This study shows that healthy older individuals managed to maintain their standing balance during a brief exposed to 32 °C but had their performance on a more demanding weight-shifting ability test negatively affected by heat. Our intention was to reproduce a situation in which a subject leaves a thermoneutral environment and enters another with high temperature, as someone who goes out the street.

Studies on the impact of environmental temperature on postural stability of elderly people are exceedingly scarce. Until the date of our review of the subject we found only one study in the elderly. Recently Lindemann at al [21] studied the effect of indoor temperature on physical performance of 81 older adults (mean age 80.9 years) during days with normal temperature and heat waves. The maximum indoor temperature recorded was 30.3 C. Habitual gait speed, chair-rise performance and static balance were assessed in the home environment of older people in absence of a heat wave and during a heat wave and it was observed that all these aspects of physical performance were negatively affected by heat .Balance was assessed by asking volunteers to stand unsupported for 10 seconds in progressively more demanding positions if possible (open stance, closed stance, semi-tandem stance, tandem stance and one-leg stance, each with eyes open) for a maximum of 50 s in total. The increase in temperature negatively affected balance only in the subgroup of adults with an initially lower gait speed (according to Fried et al.cut-offs [22]). So our results are in agreement with those presented by Lindemann [21] since our volunteers mean walking speed measured during SPPB was 1.053m / s, with the lowest observed value being 0.682m / s.

Unfortunately, the most demanding stage of the CTSIB had its assessment biased and therefore excluded from the analysis. Thus we cannot exclude the possibility that in conditions of greater demand of postural control, even healthy elderly could have their performance affected by heat.

In the present study, participants had their balance assessed after a very brief exposure to heat (some minutes for doing the handgrip). For this reason we can state that volunteers (subjects) were neither dehydrated nor hyperthermic. It´is possible that an exposure to heat enough to cause some hypohydration or hyperthermia and their related alterations such as orthostatic intolerance and alteration on cerebral blood flow could have a greater impact on balance of older adults . Regarding this issue, we cite the study of Mtibaa et al.[23] in which participants, mean age 32 years, were exposed to hot environment set to maintain core temperature at approximately 39°C. Proprioception, static and dynamic balance were negatively affected by passive hyperthermia. On the other hand, Ely et al [24] have assessed balance performance of euhydrated and hypohydrated young volunteers (mean age 22 years) at different temperatures (10^0C, 20^0C, 30^0C, or 40^0 C) without inducing hyperthermia and have shown no effect of hydration or heat and worse performance only at 10 degrees. Taking together, it suggests that hyperthermia, rather than dehydration, is the main cause for the impairment of balance, but this aspect has never been evaluated in the elderly.

In a study designed to compare postural sway between ten individuals with relapsing-remitting multiple sclerosis(MS) and nine healthy controls, participants were exposed to a warm environment (40°C, 30% RH), in which stand tests were repeated after 60 minutes of heating. Core temperature was unaffected and water loss was little for both groups. Compared to the thermo-neutral trial, postural sway during stand tests (with eyes open and closed) increased only in the MS group. These data show that healthy adults did not have their static balance negatively affected by considerable thermal stimuli. However, this level of thermal stress has never been studied in older adults [25].

Regarding dynamic balance we observed a trend for worse performance at 32 °C when compared to 24 °C in most measures, and a statistically significant difference was encountered in "End point excursion" EPE). EPE is the recommended clinical measure for this test, considered the most representative and has demonstrated excellent test-retest reliability (intraclass correlation coefficients = 0.9) [13]. As previously mentioned, Mtibba [23] has demonstrated that a possible mechanism for this heat induced change is a decrease in proprioception and in neural function.

Our sample consisted of a high percentage of physically active subjects. It is well known that the regular practice of physical exercises improves balance and decreases the risk of falls [26]. In addition, it has been shown that heat tolerance may be related to cardiorespiratory fitness (maximal oxygen uptake [V02max]) and body composition [27]. Although the effect of heat on balance was not modified by reported exercise frequency in the present study, we cannot rule out that more sedentary and mainly fragile elderly could be more vulnerable to the negative effect of heat exposure on postural control.

Some methodological limitations are noteworthy. Considering the temperature and the time of exposure, we can say that the volunteers were exposed to a low thermal stress. Humidity varied between the sessions, causing a potential loss of statistical power. The external validity of findings to the general elderly population may be limited, since our sample consisted of healthy and active older adults. Some strong points should also be noted. The order of exposures was balanced, two aspects of balance were evaluated (postural stability and limits of stability), and a training session was held in order to decrease learning effect.

Conclusion

Elderly subjects with good functional performance exposed briefly to heat were able to maintain their static postural control but had their performance in the limits of stability test impaired. Our findings may not be valid for frail and sedentary elderly populations, and further studies should investigate the impact of heat on balance and fall risk of these more vulnerable populations.

Estatement of Ethics

The Research Ethics Committee of the Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo approved the study protocol. All participants were given a full explanation of the study procedures and provided written informed consent.

Funding Sources

This study received financial support from Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP; grant number 2008-57717-6) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq; grant number 573813/2008-6)

Author Contributions

Beatriz Maria Trezza has participated in data collection, statistical analysis and funding acquisition, has written the manuscript and has prepared the figures and tables. Fábio Luiz Teixeira Gonçalves has participated in funding acquisition and in study development. Paulo Hilário Nascimento Saldiva has participated in funding acquisition. Wilson Jacob-Filho has participated in Funding acquisition and supervision. Alexandre Leopold Busse has participated in in study development, supervision and manuscript revision.

References

1. Basu R, Samet JM. Relation between elevated ambient temperature and mortality: a review of the epidemiologic evidence. Epidemiol Rev. 2002; 24(2): 190-202.
2. Astrom DO, Forsberg B, Rocklov J. Heat wave impact on morbidity and mortality in the elderly population:A review of recent studies. Maturitas. 2011; 69(2): 99-105
3. Bunker A, Wildenhain J, Vandenbergh A, Henschke N, Rocklöv J, Hajat S, et al. Effects of Air Temperature on Climate-Sensitive Mortality and Morbidity Outcomes in the Elderly; a Systematic Review and Meta-analysis of Epidemiological Evidence. EBioMedicine. 2016; 6: 258-268.
4. Minson CT, Wladkowski SL, Cardell AF, Pawelczyk JA, Kenney WL. Age alters the cardiovascular response to direct passive heating. J Appl Physiol. 1998; 84: 1323–1332.
5. Holowatz LA, Kenney WL. Peripheral mechanisms of thermoregulatory control of skin blood flow in aged humans. J Appl Physiol. 2010; 109: 1538–1544.
6. Blatteis CM. Age-dependent changes in temperature regulation. Gerontology. 2012; 58(4): 289–295.
7. Inoue Y, Kuwahara T, Araki T. Maturation and aging related changes in heat loss effector function. J Physiol Anthropol Appl Hum Sci. 2004; 23: 289–294.
8. McGinn R, Poirier MP, Louie JC, Sigal RJ, Boulay P, Flouris AD, et al. Appl Physiol Nutr Metab. 2017; 42(11): 1232-1235.
9. Matsumura BA, Ambrose AF. Balance in the older elderly. Clin Geriatr Med. 2006; 22(2): 395-412.
10. Hsu WL, Chen CY, Tsauo JY, Yang RS. Balance control in elderly people with osteoporosis. J Formos Med Assoc. 2014; 113(6): 334-9.
11. Peng K, Tian M, Andersen M, Zhang J, Liu Y, Wang Q, et al. Incidence, risk factors and economic burden of 1fall-related injuries in older Chinese people: a systematic review. Inj Prev. 2019; 25(1): 4-12.
12. Cheng Y-Y , Chen P-Y , Hsieh W-L , Cheen J-R , Kao C-L. Correlation of the composite equilibrium score of computerized dynamic posturography and clinical balance tests . J Clin Gerontol Geriatr. 2012; 3 (2): 77 – 81.

13. Harro CC, Garascia C. Reliability and Validity of Computerized Force Platform Measures of Balance Function in Healthy Older Adults. J Geriatr Phys Ther. 2019; 42(3): E57-E66.

14. Clark S, Rose DJ, Fujimoto K. Generalizability of the limits of stability test in the evaluation of dynamic balance among older adults. Arch Phys Med Rehabil. 1997; 78(10): 1078-84.

15. Trezza BM, Apolinario D, de Oliveira RS, Busse AL, Gonçalves FL, Saldiva PH, et al. Environmental heat exposure and cognitive performance in older adults: a controlled trial. Age. 2015; 37(3): 43.

16. Batista R, Gonçalves FLT; Rocha RP. Present climate and future projections of the thermal comfort for the metropolitan region of São Paulo, Brazil. Climate Change. 2016; 136 (2): 1-16.

17. Yesavage JA, Brink TL, Rose TL, Lum O, Huang V, Adey M, et al. Development and validation of a geriatric depression screening scale: a preliminary report. J Psychiatr Res. 1983; 17(1): 37–49.

18. Folstein MF, Folstein SE, McHuch PR. Mini-mental state. A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res. 1975; 12(3):189–198.

19. Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol. 1994; 49(2): M85-94.

20. Shih MC, Wang RY, Cheng SJ, Yang YR. Effects of a balance-based exergaming intervention using the Kinect sensor on posture stability in individuals with Parkinson's disease: a single-blinded randomized controlled trial.J Neuroeng Rehabil. 2016; 27;13(1): 78.

21. Lindemann U, Stotz A, Beyer N, Oksa J, Skelton DA, Becker C, et al. Effect of Indoor Temperature on Physical Performance in Older Adults during Days with Normal Temperature and Heat Waves. Int J Environ Res Public Health. 2017; 14;14(2).

22. Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiener J, et al. Frailty in older adults: Evidence for a phenotype. J. Gerontol. 2001; 56, M146–M156.

23. Mtibaa K, Thomson A, Nichols D, Hautier C, Racinais S. Hyperthermia-induced Neural Alterations Impair Proprioception and Balance. Med Sci Sports Exerc. 2018; 50(1): 46-53

24. Ely BR, Sollanek KJ, Cheuvront SN, Lieberman HR, Kenefick RW. Hypohydration and acute thermal stress affect mood state but not cognition or dynamic postural balance.Eur J Appl Physiol. 2013; 113(4): 1027-34.

25. Poh PYS, Adams AN, Huang M, Allen DR, Davis SL, Tseng AS, et al. Increased postural sway in persons with multiple sclerosis during short-term exposure to warm ambient temperatures. Gait Posture. 2017 M; 53: 230-235.

26. Lelard T, Ahmaidi S.Effects of physical training on age-related balance and postural control. Neurophysiol Clin. 2015; 45(4-5): 357-69

27. Lisman P, Kazman JB, O'Connor FG, Heled Y, Deuster PA. Heat Tolerance Testing: Association Between Heat Intolerance and Anthropometric and Fitness Measurements. Mil Med. 2014; 179(11):1339-46. below.