Bull. Fac. Ph. Th. Cairo Univ., Vol. 19, No. (2) Jan. 2014

GAIT CHANGES IN RESPONSE TO CARRYING A UNILATERAL LOAD IN COMMUNITY DWELLING ELDERLY

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ABSTRACT

Introduction. Falls are the leading cause of death from injury in persons older than 65. Understanding of the interaction between intrinsic and extrinsic variables that lead to falls may help clinicians provide recommendations and guidelines as to the maximum amount of external weight that an older adult can carry safely. **Purpose.** The purpose of this study was to determine the effects of carrying a unilateral load on gait in community dwelling elderly. **Subjects and methods.** Subjects were healthy, community-dwelling elders aged 65 years and over. They were asked to walk the length of a platform (containing a force-plate) at a comfortable speed carrying zero pounds, five pounds, or ten pounds of weight. A successful trial occurred when the foot on the same side as the weight fully came in contact with the force-plate. Two successful trials were performed for each weight. Repeated measure ANOVA was used to measure the differences in forces generated in the antero-posterior direction and changes in center of pressure as a result of unilateral loading using the three weights with the use of the force plate. **Results.** The results showed no significant differences among the three levels of the independent variables ($p = .05$). **Conclusion.** The results indicated that carrying up to 10 pounds of unilateral weight did not make a significant difference in ground reaction forces during the stance phase of gait and did not excede the anterior-posterior or the medio-lateral limits of stability on the side of the weight among healthy community-dwelling elderly adults.

INTRODUCTION

As the general population gets older, there are age-related changes that may occur. Some of these changes have an impact on the gait cycle of the older adult. Age-related changes affect the musculoskeletal, cardiopulmonary, neuromuscular, integumentary, and cognitive systems. Changes in the musculoskeletal system usually present as changes in muscle strength and range of motion (ROM) that may lead to impairment. According to Shumway-Cook and Woollacott (2007), muscle strength in the lower extremities can decrease by as much as 40% between the ages of 30 and 80 years. The muscle groups that are of primary concern are the knee flexors, extensors, and ankle dorsiflexors. These muscles play a major role in balance and proprioception.

Range of motion and flexibility may also decrease with age. Between the ages of 55 and 85 years, flexibility decreases by 50% in women and 35% in men (Vandervoort et al., 1992).

Strategy mechanisms to help maintain balance and age related alterations with the addition of perturbations are believed to be the cause for balance and postural control problems of the older adult. Older adults tend to coactivate antagonist muscles along with agonist muscles at a given joint more than younger adults do (Shumway-Cook and Woollacott, 2007). It was also stated that older adults use hip strategies more than ankle strategies to keep their balance when compared to younger adults.

Another system that may change with the aging process is the neuromuscular system. Peripheral neuropathy is a common cause of sensory limitations in the extremities. Sensory limitations can lead to problems with balance and gait (Shumway-Cook & Woollacott, 2007). Another major change related to aging is vision in regards to the visual field and visual acuity, which may cause loss of depth perception further leading to balance and gait difficulties (Pastalan Mantz, & Merrill, 1973; Pitts, 1982).

Many falls in the elderly occur while walking with changes in parameters such as temporal, spatial, and muscle activation contributing to gait changes (Vandervoort et al, 1992; Shumway-Cook & Woollacott, 2007).

Falls are the leading cause of death from injury in persons older than 65 years and represent a large percentage of annual health care costs (Guccione, 2000). Therefore, with the increasing costs and high mortality rates associated with falls, it is imperative that a high priority be placed on fall prevention.

There are many tests that can be used by physical therapists to determine one's risk of falling which can be useful in determining a fall prevention plan. Researchers can use tools such as force plate and three dimensional gait analyses which have significant advantages over observational gait analysis. Motion and force analysis equipment allow researchers to gather objective and quantitative measures in regards to any change in joint angulations, distribution of weight in limbs during stance phase in response to an external load (Dutton, 2008).

In order for fall prevention to be successful there are needs to of understanding of the interaction between intrinsic and extrinsic variables that lead to falls. Intrinsic variables refer to characteristics such as balance, muscle weakness, poor hearing and vision or neurological disease. Extrinsic variables include the impact of environment such as slippery surfaces, poor lighting and tripping hazards such as rugs. Unilateral loading is another example of an extrinsic risk factor that may increase an individual's risk of falling. The purpose of this study was to investigate the effects of unilateral loading on the quality of gait in older adults. Understanding this interaction may help clinicians provide recommendations and guidelines as to the proper technique and or maximum amount of external weight that an older adult should be carrying safely. This would therefore be an important part of patient education which is a key component of an effective prevention program. It can be hypothesized that when elderly individuals carry a unilateral load, lateral displacement may cause that individual to exceed their limit of stability.

MATERIAL AND METHODS

Data were collected from twenty independent, community dwelling elders. Inclusion criteria for participants included being a healthy, independent individual from the greater Utica area over the age of 65 years. Participants also had to be able to understand verbal commands, ambulate without an assistive device, as well as hold and carry a weighted object. Exclusion criteria for participants included having any cognitive, visual, neuromuscular or musculoskeletal disorders. Also, if the participant had any significant injuries or any major surgeries within six months of testing they were excluded from the study. Finally, any participant with a history of falls, frequent falls within a short period of time, or those found to be at a high risk for falls were also excluded from the study.

Research Design

For this study a quazi-experimental, within-subject, one way repeated measure design was used. Each participant was tested under three levels of the independent variable; which was the amounts of weight that each subject was asked to carry. These were holding zero weight, five pounds of weight, and lastly the participant held 10 pounds of weight on the right hand.

All of the trials were done randomly so that the subject did not expect a change in weight and was not able to use compensatory strategies in regards to the amount of weight carried. Each condition consisted of walking onto a force plate while holding a weight while data was collected regarding center of pressure; from this data we were able to estimate limits of stability. Each condition was performed until the researchers were able to obtain two successful trials on each subject. The research team then filtered data from the six successful trials of each participant. The dependent variable in this study was the data that was collected from the force plates regarding center of pressure and limits of stability.

Materials

For the purposes of this study, the researchers chose to use only a portion of the Multi Direction ReachTest , which were the forward and lateral reach to the right to measure the maximum amount of forward and lateral movement to the right that participants can reach while standing with a fixed base of support (Jonsson, Henriksson, & Hirschfeld, 2002).

Sit-to-Stand Test. The sit-to-stand test is a tool used to measure one's lower extremity strength as well as balance. This test has also been used as a fall predictor and to determine difficulties with postural control. This test is easy to administer and is a common tool used by many clinicians. There are disputes among clinicians as to how many sit-to-stands should be performed during the test, but many clinicians tend to use five sit-to-stands. This test consists of having an individual start in a seated position, then stand without using their arms to push off the chair with, and then sit back down. The amount of time it takes to complete the task is recorded and it has been suggested that the longer the time it takes to complete the test, the higher risk the individual has for falling (Whitney et al., 2005).

Timed Up and Go Test (TUG). This test requires the participant to stand up from a standard chair without the use of arm rests, walk 3 meters, turn around and walk back to the chair, and then sit back down. Use of the TUG has been recommended when determining risk for falls among elderly by organizations such as the British and American Geriatric societies (Nordin, Rosendahl, & Lundin-Olsson, 2006).

Force plates. In this study, piezoelectric Kistler force plate was used to measure the amount of weight that was displaced during the activity. Force plats is able to measure center of pressure by recording the ground reaction force data from the moment the participant steps onto the plate via the sensors located in the force plates (Karlsson & Frykberg, 2000). The force plate is connected to a computer and using the Vicon Motus software, it is possible to collect information when pressure is applied to the force plate. Force plate can be used to determine the vertical ground reaction force, which is the force acting on the body from the ground (Haas & Burden, 2000). These measurements obtained from the force plates can help to observe movement strategies that participants use in reaction to the task they are given to complete.

Procedure

Research was conducted at the Physical Therapy Research Laboratory at Upstate Cerebral Palsy located in Chadwicks, New York.

An initial screening was acquired prior to testing. The data collected during the initial screening included height and weight as well as a gross strength examination, a screen for balance and a screen for mobility. Every participant was asked to perform ten heel raises on each leg, the sit-stand test, and the TUG test.

Participants were then asked to perform the functional reach test (FRT) on the force plate without moving their feet, lifting their heels, or taking a step. The participants were asked to complete two successful trials of this task and an average of the numbers was taken. The distance the participant was able to reach was measured with a ruler that was placed along the path of their arm (figure 1).

Figure 1: Participant performing FRT

Next, each participant was asked to perform the lateral reach test. This was similar to the FRT completed; only this test required the participant to reach as far to the right as they could. Once again, the participants were asked to complete this task without moving their feet, lifting their heels, or taking a step. They were each asked to complete two successful trials for this task as well and an average was taken of these results obtained from the ruler. The functional and lateral reach tasks were used to obtain information regarding each participant's limits of stability.

After performing the FRT and lateral reach test, participants were ready to perform the gait component of the study. During the testing, participants were then asked to complete two successful trials while carrying three different weights (0, 5, 10 lb) in a random order. Participant carried the weight in their right hand while walking on the platform. A successful trial occurred when the foot, on the same side as the weight, landed on the force plate.

Data Analysis

While screening the data, it was found that the data of two subjects would need to be omitted from the study. One subjects' data was removed because they were more than 2.5 standard deviations away from the mean. The second subjects' data was removed because the subject was unable to successfully complete the desired tasks safely, so this data was removed as it was not representative of the rest of the population being studied.

RESULTS

Subject Characteristics

Twenty participants were recruited and agreed to partake in this study. Data from 18 participants were used (n =18). The average age was 72.56 $\pm$ 5.29 years with an average height of 164.7cm and an average weight of 77.54 kg. In this study there were six males and 12 females. When comparing themselves to individuals of the same age group, 55% of participants reported more than average level of physical activity while 45% reported average level of physical activity.

Clinical Data

Clinical testing was performed to determine participants' mobility and balance and determine if any of the participants should be excluded from the study. The clinical tests used for gait was the TUG test. The forward reach and lateral reach were used to determine the limits of stability (LOS) of the participant. The mean and standard deviation for the TUG scores were 7.41 $\pm$ 1.65 seconds (range 4.0-10.2 seconds). The mean and standard deviation for the forward reach and lateral reach were 29.46 $\pm$ 4.84 centimeters (range 21.59-43.18 centimeters) and 15.38 $\pm$ 3.31 centimeters (range 8.89-21.59 centimeters) respectively.

Force plate

Results are expressed as mean ± standard deviation (SD). Comparison between the mean values of different variables measured at zero, five and ten pounds was performed using repeated measure ANOVA. Statistical Package for Social Science (SPSS) computer program (version 19 windows) was used for data analysis. P value ≤ 0.05 was considered significant.

The mean and standard deviation of the breaking (anterior) and propulsion (posterior) forces for zero, five and ten pounds of weight with the percentage of time it occurred in the stance phase of gait are shown in table one.

Table 1. Mean and Standard Deviation (SD) of Force and Percentage of Time representing the sub-phase of gait when each force occurred during the Stance Phase of Gait

Variables	0 lb (n= 18)	5 lb (n= 18)	10 lb (n= 18)	F test	P value
Propulsion force (N)	96.0 ± 32.1	95.8 ± 30.6	99.6 ± 31.0	3.267	0.052
Propulsion time (%)	22.8 ± 1.2	24.5 ± 9.2	23.0 ± 2.0	1.223	0.307
Breaking force (N)	124.3 ± 30.9	122.2 ± 31.0	123.2 ± 31.2	1.120	0.332
Breaking time (%)	81.3 ± 1.3	80.0 ± 4.5	81.4 ± 1.6	1.738	0.197

During walking with no weight (0 lbs.) the average propulsion force was 96.0 ± 32.1 N during 22.8 ± 1.2 % of stance phase while the average breaking force was 124.3 ± 30.9 N during 81.3 ± 1.3% of the stance phase. When participants walked with five pounds of weight the average breaking force was 122.2 ± 31.0 N and the average propulsion force was 95.8 ± 30.6 N. These forces occurred at 80.0 ± 4.5% and 24.5 ± 9.2% of the stance phase, respectively. While walking with the ten pounds weight the average breaking force was 123.2 ± 31.2 N during 81.4 ± 1.6% of the stance phase while the average propulsion force was 99.6 ± 31.0 N occurring at 23.0 ± 2.0 % of the stance phase.

Table (2) represents the mean and standard deviation of the excursion displacement anterior to posterior and medial to lateral. This represents how much an individual's foot moved during the transitions from swing phase to stance phase and back to swing phase during zero, five and ten pounds of weight.

Table 2. Mean and SD of COP excursion in X and Y directions

Excursion	0 lb (n= 18)	5 lb (n= 18)	10 lb (n= 18)	**F test**	**P value**
COPx	0.18 ± 0.04 m	0.23 ± 0.06 m	0.19 ± 0.03 m	0.841	0.425
COPy	0.05 ± 0.02 m	0.05 ± 0.02 m	0.05 ± 0.01 m	1.446	0.251

*Note: COPx is the center of pressure excursion in the anterior posterior direction; COPy is the medial lateral excursion.

During 0 lb condition the participants produced an average COP excursion in the anterior-posterior direction of 0.18 ± 0.04 m and in the medial-lateral direction of 0.05 ± 0.02 m. When participants walked with five pounds of weight the average COP excursion in the anterior-posterior direction was 0.23 ± 0.06 m and in the medial-lateral direction was 0.05 ± 0.02 m. While walking with the ten pounds weight the average COP excursion in the anterior-posterior direction was 0.19 ± 0.03 m and in the medial-lateral direction was 0.05 ± 0.01 m (Table 2).

DISCUSSION

The results of the study showed that unilateral loading did not make a significant difference in ground reaction forces during the stance phase of gait. Abnormalities in temporal and spatial characteristics of gait can be assessed by comparing these forces and corresponding percentages to values commonly reported for normal gait, such as the Ranchos Los Amigos Observational Gait Analysis (RLA OGA) system. In our study, the minimum force in the anterior-posterior direction occurred at approximately 22-24% of the stance phase, which corresponds to the mid-stance phase of gait. According the RLA OGA, the transition of body's COG over the support foot during normal gait occurs at 10%-30% of the total gait cycle. The maximum force in the anterior direction in our study corresponded to approximately 80% of the total stance phase of gait. At this point in the gait cycle the body's COG is shifted anterior to the BOS as the lower extremity is forcefully plantarflexed to prepare for the transition into swing phase. In normal gait, this transition occurs at approximately 80-90% of the total stance phase of gait (Perry et al., 1993).

Our results also showed that carrying a unilateral load did not make a significant difference in the COP excursion as measured by total excursion in the anterior-posterior and medial-lateral directions (Table 2). Measuring differences in total COP excursion between loading conditions COP allowed us to assess postural stability because the COP oscillates in either direction in a predicable manner throughout the gait cycle. The total excursion values in the anterior-posterior direction ranged from 18 cm-23 cm. At the point of initial contact the COP located posterior to the BOS and travels anterior as the body transitions to the swing phase. Similarly, the COP also oscillates in the medial-lateral direction during the gait cycle. We hypothesized that if a difference truly existed it would be in the medial-lateral direction because the body acts as an inverted pendulum and is pulled in the direction of the weight. However, the results showed no difference in total excursion of COP in the medial-lateral directions regardless of loading condition. The mediolateral COP excursion corresponded to an average value of 5 cm for all conditions.

There are a number of possible explanations as to why our results showed no significant change in medial-lateral displacement while carrying a unilateral weight as stated in our hypothesis. First, healthy community dwelling elderly adults have adequate strength and adaptive strategies to counteract the effects of a relatively light unilateral load, as was the case in the earlier study conducted by Matsuo et al. (2008). In fact, the researchers in this study concluded that more body segments were progressively recruited with identical patterns identified with increasing weight. This pattern followed a logical sequence that included contralateral trunk and head pitch and contralateral shoulder abduction when hip torque alone was not adequate to maintain postural stability.

Secondly, the weights we used may have been too small to detect a significant change. The study conducted by Crowe & Samson (1997) found a significant change in COP displacement in middle aged adults in which each participant carry 15% of their total body weight (150 lbs. = 22.5 lbs.), which was significantly higher than the 10 lbs. our participants carried. However, even community dwelling elderly adults in the study conducted by Matsuo et al. (2008) required participants to carry a weight of 17.5 lbs.

Thirdly, carrying a unilateral weight while ambulating is not complicated enough to be considered a dual-task condition. Toulette et al. (2006) found no significant gait differences between elderly participants with and without a history of falls under a single ambulation task. However, gait characteristics were significantly different in the participants with a history of falls when ambulating while carrying a full glass of water. In this case, carrying a glass of water is considered a dual task because it requires significant fine motor coordination and concentration. In contrary, many activities of daily living require us to carry uneven loads on a regular basis throughout the course of our life, and it becomes an almost automatic skill requiring little attention to perform. Therefore, it is not surprising that completing this familiar task does not degrade a healthy individual's motor performance unless the weight is heavier than normal or requires significant amounts of concentration to handle (Hollman et al., 2007).

Lastly, differences in gait performance or adaptive strategies may have been present but we were unable to detect them. Studies had shown that patients with a history of falls ambulate at slower speeds by decreasing their stride length and step frequency. Barak et al. (2006) showed that elderly participants with a history of falls had less medial-lateral sway compared to a non-falling group while ambulating on a treadmill at identical speeds. Furthermore, the results showed that medial-lateral sway significantly increased at higher speeds of ambulation. In the case of our study, participants may have maintained postural stability by decreasing the speed of their ambulation.

A number of limitations may have been present in the present study. We may have not an adequate number of participants for a high enough power to detect a difference. In addition, the variability of performance may have made the standard deviation too high to show a significant difference. The method we used to calculate LOS could have also limitations in our results because we used 50% of the LOS when performing the LR only to the right side however we did not really account for the LOS during data analysis.

Future studies should take these limitations into account, along with a few additional recommendations. First, comparing a healthy elderly population to a younger population may in fact show significant differences in postural stability that were not detected in the present study. Second, conducting a study using heavier weights would help provide additional recommendations for reducing fall risks by setting a limit on the maximum amount of weight that can be safely carried. Lastly, using motion analysis or an additional force plate to explore additional gait characteristics, joints moments, or compensation strategies may identify significant performance differences between community dwelling elderly adults. Study the impact of carrying a unilateral load on individuals who have lower extremity impairments such as weakness or balance dysfunction should also be investigated.

In conclusion, this study provides evidence that carrying up to 10 pounds of unilateral weight does not increase the medio-lateral limits of stability on the side of the weight among healthy community-dwelling elderly adults. This information may be used by clinicians to provide education to patients in regards to prevention. Indecently, preventative education is an area of falls prevention that lacks research when compared to intervention strategies. Future work that identifies the maximum allowable weight that can be safely carried by this patient population will further assist clinicians in providing safe recommendations to prevent falls.

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الملخص العربي

تغيرات المشي استجابة لحمل وزن أحادي الجانب في المسنين المتعايشين مع المجتمع

كان الغرض من هذه الدراسة تحديد الآثار المترتبة على تحمل ثقل أحادي الجانب على المشي عند المسنين المتعايشين مع الجتمع. لذا أجريت هذه الدراسة على مجموعة من المسنين الأصحاء تعيش في المجتمع تتراوح أعمارهم بين 65 سنة وأكثر. وطلب منهم أن يمشوا على ممشى يحتوي على لوحة تحليل قوى و ذلك بسرعة مريحة وهم يحملون أوزاناً مختلفة (صفر، أوخمسة أو عشرة أرطال) وكان الاختبار يعتمد على أن تأتي القدم على نفس جانب الوزن المحمول على اتصال مع لوحة تحليل القوى. أجريت محاولتان ناجحتان لكل وزن. تم استخدام تحليل متعدد انوفا لقياس الاختلافات في القوى الناتجة في الاتجاه الأمامي الخلفي و كذلك التغيرات في مركز للضغط نتيجة لتحميل غير متماثل باستخدام الأوزان الثلاثة مع استخدام لوحة تحليل القوى. أظهرت نتائج الدراسة عدم وجود فروق ذات دلالة إحصائية بين المستويات الثلاثة في المتغيرات المستقلة.

وأشارت نتائج الدراسة أن حمل أوزاناً تصل الى 10 رطلا من الوزن غير المتماثل لم يحدث فارقا كبيرا في قوة ردفعل الأرض الواقع خلال مرحلة التحمل اثناء المشي ولم يتجاوز حدود الاستقرار الأمامي-الخلفي، أو الجانبي بين المسنين الأصحاء الذين يعيشون في المجتمع