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Original Article

Improve elderly people's sit-to-stand ability by using new designed additional armrests attaching on the standard walker

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Abstract

Background: More and more elderly problems come to our life and the elderly health care become more important. Elderly people with lower extremities weakness usually use walkers to assist in walking. Although the commercial standard walkers (N-type) can improve elderly people's walking ability, users sometimes take risk of falling when using the standard walkers to perform sit-to-stand (STS). The purpose of this study is to design an additional armrest which can be attached to a standard walker for users performing STS more easily and evaluate it with clinical assessments and a body worn sensor.
Methods: The combination of the walker and the new armrest design are referred to as a better type (B-type). Clinical assessments and a motion analysis were performed on 34 elderly people (age, 83 ± 6 y/o) with a Five Times Sit-to-Stand Test (FTSST), a satisfaction survey and an inertial measurement unit (IMU) attached to the trunk to measure the acceleration data when using B-type and N-type during STS.
Results: The FTSST result shows that the B-type can reduce about 5 s spending time of elderly people during STS and 63.7% of subjects were more satisfied on the B-type than the N-type. According to the IMU, the result reveals that the B-type can provide subjects higher peak–peak anterio-posterior acceleration, peak flexion acceleration and peak extension acceleration during STS.
Conclusion: There is a better assistance during STS when using our new armrests design combined with the commercial product which could provide larger acceleration to perform sit-to-stand.

Keywords: Acceleration; Elderly; Five times sit-to-stand test; Inertial measurement unit; Sit-to-Stand; Walker

1. Introduction

Many developed countries are on course to go from being an aging society to an aged society. Falls are one of the common and serious problems among elderly people. Most of these falls are associated with weaker balance controls, and these conditions may also have identified as some risk factors.

Factors affecting the balance conditions of elderly people include visual system, vestibular system, somatosensory system, muscle strength and reaction time.[1,2] As lower extremities weakness is one of the common problems that causes imbalance in elderly adults,[3] walkers are usually use to assist in walking. There are two functions that a walker must require: (1) Weight-bear and keep balance when walking, (2) Sit-to-

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stand assistance.[4] Standard walker (called N-type in this article) and UpRise Onyx Folding Walker (called R-type) which is a combination of folding walker and rising aid are the commercial products showed in Fig. 1. The height of armrest of N-types walker was designed for users to walk, but not easily used in performing sit-to-stand. The reason is that the armrests are too high to apply downward force by hand for sit-to-stand assistance if the user has lower extremities weakness. In another commercial product, R-type walker is designed in armrests with two levels. The high level is as high as N-type walker for users well used in walking and the low level is 10 cm lower than N-type walker armrests to assist users in performing sit-to-stand. However, the low level armrests are designed in the backend of the walker. In clinical phenomenon, users' COM will be backward in the base of support and cause the user have higher fall risk when holding low-level armrests when using R-type to perform sit-to-stand. As a result, the R-type walker is still considered not a well design for users.[5]

Many researchers have conducted some experiments on the stability of sit-to-stand.[6] One of the well-used methods is the Sit-to-stand test. The Sit-to-Stand Test has been used to identify some clinical assessment, including postural control, fall risk, lower-extremity strength, proprioception and as a measure of disability. The Five Times Sit-to-Stand Test (FTSST) has been related to standing and postural control and to falls in older adults.[7] Furthermore, the FTSST is suitable for subjects with disability according to the advantage of in expensive equipment and without space constraints. Many researches have investigated the validation of FTSST data with other clinical tests and suggested that the FTSST is a valid measure of dynamic balance and functional mobility in older adults.[7–11]

In addition to clinical assessment, some electrical devices were used to identify the clinical assessment recently. The force plate and motion capture system are the most common used devices to evaluate the fall conditions of elders.[12] In these years, the inertial measurement unit (IMU) is one of the options in motion analysis. An IMU sensor could provide precise measurement. It has replaced the force platform as a clinical assessment device because the properties of an IMU including portable and inexpensive.[13] The portable trait make IMU sensors have well useful in experiment out lab door and the small volume make the IMU well attached to a subject's chest or pelvis.[14–16] The IMU will not cause uncomfortable to the subject. Using the three-dimensional acceleration and velocity measuring ability of IMU, the subject can be measured anterio-posterior (AP), medial-lateral moving (ML), and superio-inferior data (SI) base on the defined axes.[14,16] Among the sit-to-stand, the AP and SI data can reflect the subject's stability more directly.[17] Some researchers also use IMU to study motion properties in daily activities such as walking, running, standing, sitting and brushing teeth.[17,18] Moreover, the IMU can determine the difference of balance performance in different groups of people such as evaluation the difference of sit-to-stand in elders and youngsters.[19]

The purpose of this study is to design an additional armrest on the standard walker in order to assistant on performing sit-to-stand with the elderly, and to evaluate the consequence by using clinical assessment and a body worn sensor.

2. Methods

A new design of components for walker were successfully modified the N-type walker. The new design was assumed as a better type and referred as B-type in this article. For B-type, two armrests which were 10 cm lower than N-type were attached to both sides of middle bars on N-type to provide two better force exertion places in performing sit-to-stand (Fig. 2).

(a) (b)

Fig. 1. Different type of commercial walker: (a) N-type, (B) R-type.

The components were fabricated with stainless steel. The weights of these three additional armrests are all smaller than 20% weight of the N-type. Two methods, clinical assessments and motion analysis were performed to evaluate the difference between our new design and commercial products.

2.1. Participants

34 elderly people were recruited in this study, including 25 males and 9 females (age, 83 ± 6 y/o, range: 64−96 y/o; height, 159.6 ± 5.0 cm, range: 143−172 cm; weight, 76.3 ± 9.8 kg, range: 49−92 kg). Elderly people who unable to perform sit-to-stand by themselves and have used an N-type walker before were included in this study. The exclusive criteria were that the elderly people have hearing impaired, unclear articulation, Parkinson or stroke patients.

2.2. Procedure

The experiment was conducted by measuring spending time of sit-to-stand and satisfaction when using the new type of walker.[8,20,21] A 3-Space Sensor (YEI Technology, Ohio, US) was used as an IMU sensor to evaluate the B-type in this study. The sensor combined with an elastic rope was put on subject's chest firmly on avoiding further movement on chest (Fig. 3).[8] When the sensor was exactly attached to the subject, the subject was instructed to perform sit-to-stand with the FTSST. In all kinds of the data, which were obtained from the YEI sensor, and acceleration data of performing sit-to-stand were extracted from the free download software (YEI Technology, Ohio, US). The FTSST was started from physician instruction. The physician provided the following instructions according to the standardized laboratory protocol: "I want you to stand up and sit down as quickly as you can when I say 'Start'." Timing began when the physician said "Start" and stopped when the subject stood up fully. Subjects were allowed to place their feet comfortably under them during testing. In this study, all of the tests were randomly order and executed by physician to avoid learning effect and fatigue of patients. Each test was repeated in 5 times for both B-type and N-type walker. Totally, there are 10 trials for each subjected within 2 types of walker × repeat 5 times for each type. The examiner recorded the time which subject spent to complete the test and polled the participants about the satisfaction at the end of experiment. The satisfaction test is performed with

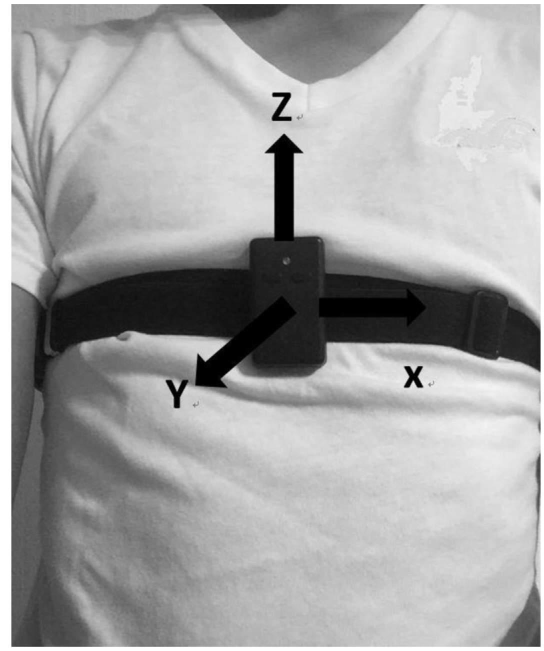

Fig. 3. IMU detachment position and the definition of three direction (x-direction: medial-lateral movement; y-direction: anterio-posterior movement; and z-direction: superio-inferior movement).

(a) (b) (c)

Fig. 2. B-type armrest after modification: (a) top view, (b) front view and (c) side view.

three levels (better, the same and worse) in comparison of B-type and N-type.

2.3. Data analysis

The FTSST and satisfaction data were graphed as bar chart. To compare the FTSST of B-type, N-type, an independent t-test was performed on these two types of armrests.

The acceleration from YEI software was exported into Origin 9.1 (OriginLab, MA, US) to graph the data from points to curves. The axes were defined as shows in Fig. 3. Three directions of data were plugged into curve individually (x-direction presents ML movement; y-direction presents AP movement; and z-direction presents SI movement). In acceleration data, peak-to-peak (P2P) acceleration is determined as the absolute acceleration in sit-to-stand, which is either from AP acceleration initiation to seat off or from seat off to AP acceleration termination. Peak flexion acceleration is the amplitude of first peak, and peak extension angular velocity is the amplitude of second peak.[22] Due to the individual difference, a pair T-test was performed for comparison of the P2P acceleration, peak flexion acceleration and peak extension acceleration between N-type and B-type. The Statistical Package for Social Sciences version 22.0 (SPSS 22.0, SPSS Inc., Chicago, USA) was used with the significant level of the above tests was set at 0.05.

3. Result

Fig. 4 (a) represents the reduction of STS pending time in using B-type than N-type during STS. Elderly people using B-type walker to perform sit-to-stand can reduce about 10% spending time compared to N-type, shown in Fig. 4A. With statistical analysis, there are significant difference between B-type and N-type ($p < 0.05$). In satisfaction result, 63.7 percentage of these 34 subjects also gave B-type better evaluation (Fig. 4B).

The acceleration pattern of AP and SI direction from initial to steady standing was shown in Fig. 5. In total five events are identified, (1) Initiation, (2) Maximum peak flexion acceleration, (3) Minimum peak extension acceleration, (4) Seat off and (5) termination from gyroscope data. Table 1 presents the means, standard deviations, and probabilities of differences ($p < 0.05$) for all dependent variables evaluated in this study. STS with B-type armrests shows higher peak−peak anterio-posterior acceleration than STS with N-type ($p < 0.005$). Additionally, subjects also got higher peak flexion acceleration ($p < 0.05$) and peak extension acceleration ($p < 0.005$) with B-type than N-type during STS (Table 1).

4. Discussion

There is preliminary test for the performance of sit-to-stand by different types of additional armrest in this study, then the final design (B-type) is according to the preliminary result. This lightweight and scalable design can improve patients' mobility. The FTSST result of elderly people with balance dysfunction in our study indicated that they had significant impairment. Seeman et al.[23] reported a result of 12.3 s for the FTSST in people who were 70−79 years of age, whereas elderly people with using B-type in our sample had a FTSST results of 11.39 s. Guralnik et al.[24] reported mean scores of 15−16 s in men and women older than 80 years. Lord et al.[11] reported FTSST scores were 12.1 s for men and 12.2 s for women in the age range of 70−79 years. These results similar to our reported data. Both FTSST result and the satisfaction investigation showed that elderly people prefer to use B-type caused by two reasons. First, lower heights of armrests could provide subjects exert downward force with hands to assist subjects with sit-to-stand performance. The commercial product, R-type and our designs, B-type both provide lower height of armrests than N-type. Second, the problem of R-type is that the base of support is smaller than the other two types. The B-type provides the same base of support as N-type because the additional armrests are still inside the walker. In this step of study, most elderly people were measured that using B-type may spend less time to perform sit-to-stand but some of them feel unsatisfied on the design of B-type. The reason may cause by these elderly people feel annoying with

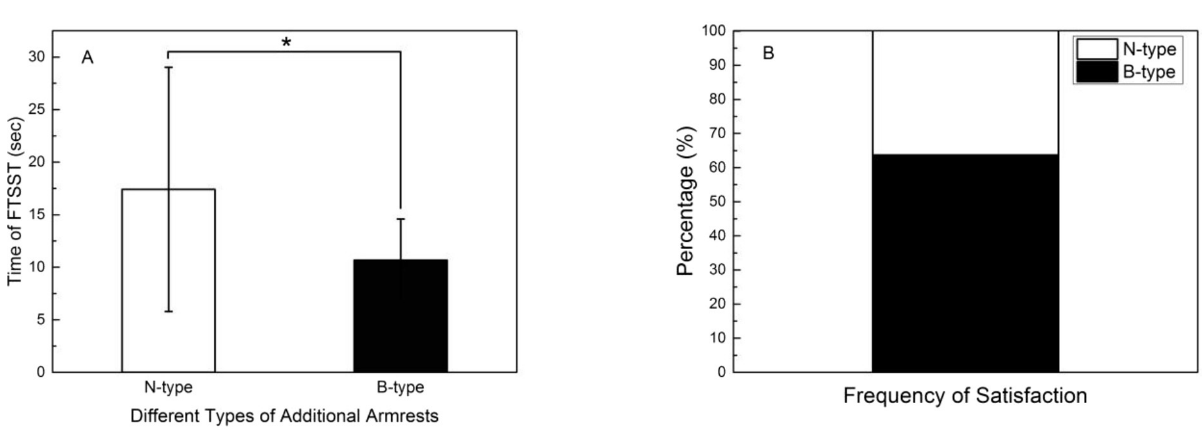

Fig. 4. (A) Mean time of 34 subjects FTSST with two types of armrests (B) Satisfaction survey in 34 subjects.

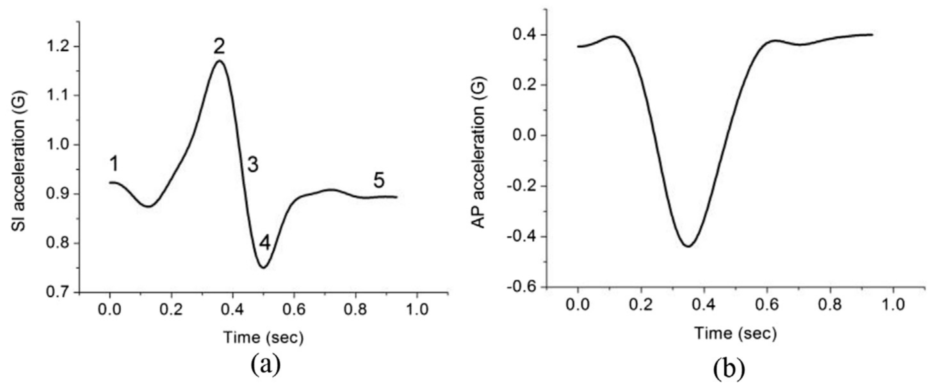

Fig. 5. Trunk acceleration in IMU data (a) superio-inferior direction (1 Initiation, 2 Maximum peak flexion acceleration, 3 Minimum peak extension acceleration, 4 Seat off and 5 termination) (b) anterio-posterior direction.

the shifting movement from additional armrests to the original armrests. In sum, the advantage of B-type is that it provides the patients or elderly people faster performance in sit-to-stand. The sit-to-stand stability when using our new designed will be compared with body worn sesnsors of this study.

Body worn sensors can be used to determine STS in non-laboratory environments. The analogous parameters found by the IMU sensor in general follow the STS behavior numerically and statistically. The acceleration figure from electrical device measurement shows that there is a specific pattern in each direction. These patterns represent subjects swing their trunks during the whole process for the purpose of performing STS easier. The trunk movement may come from elder's lower extremity weakness with swing their trunks to produce impulse to perform STS more easily. This phenomenon is also congruent to other research.[19,20] In three dimensions of data, the AP and SI direction are the dominant parameters in this study because of the movement is affected directly by trunk “forward” and standing “up”. Moreover, the curve in AP and SI direction is similar to the conventional STS curve.[22] In AP direction, there is an accelerated pattern in the beginning which shows that subjects' trunk moves forward and followed with a decelerated pattern until steady standing. The SI direction of STS pattern in using B-type is more similar to normal people than subjects using N-type or other types.[16–19] The STS acceleration curve in AP direction of a normal person can be easily distinguished into a simple sin wave. This motion strategy is congruent to the results, which is obtained by Zijlstra et al.[15] and Doheny et al.[14] Elderly people generate high flexion and extension momentums in using B-type as compared to using N-type. As high flexion accelerations are created in B-type, just before seat off and followed by high deceleration after seat off, this is to counter the already self-generated momentum. Thus, standing up using N-type may present an extra challenge at seat off to elderly people. Also, elderly people may fail to generate or counter momentum at seat off due to weak muscles and may result STS difficulty.

Table 1
STS Parameters defined using IMU.

IMU Parameters	N-type	B-type	Pair t-test (p)
P2P AP acceleration [g]	0.66 ± 0.26	0.77 ± 0.28	0.001
Peak flex. acceleration [g]	0.11 ± 0.76	0.19 ± 0.18	0.018
Peak ext. acceleration [g]	0.23 ± 0.12	0.28 ± 0.12	0.003

Although the armrests of B-type which are lower than N-type could provide better places for hands apply force. Subjects with lower extremities weakness could therefore use upper extremities to perform sit-to-stand more easily when using B-type. In preliminary study, different positions and heights of additional armrest were tested on patients' performance of sit-to-stand. The center of gravity (COP) shifted by the B-type is low enough for patients to stand up by the new armrest more easily. In addition, excessive of COP shifting may cause danger so the B-type maintains the user's COP inside the base of support of the walker to keep the patient stable. Besides, the resistance of armrest in downward force is the body weight of a 100 kg person and more standard tests will be conduct in the future. In our study, not all the subjects perform sit-to-stand well in B-type; a few of these 34 subjects present equal contribution with B-type and N-type; and a few present B-type is worse than N-type. We assume that subjects with equal contribution between B-type may have strong lower extremities without using much upper extremities against the purpose of this study. With upper and lower extremities muscle weakness, subject may have worse performance with using the new design of modification. But both these assumptions need to be proved with further experiments. The material of additional armrests in this study is stainless steel. In future study, the aluminum alloy can be an alternated material to make our design lighter.

In conclusion, a new designed of additional armrests attaching on the commercial standard walker has been evaluated in this study to address the clinical need of performing STS using a body worn sensor. The new additional armrests can provide elderly people spending less time during STS, greater satisfaction and higher acceleration in AP and SI direction. As a result, the combination of additional armrest design and standard walker is an efficiently assistance for the elderly people in performing sit-to-stand.

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References

1. Sturnieks DL, St George R, Lord SR. Balance disorders in the elderly. *Neurophysiol Clin* 2008;**38**:467−78.
2. Perry MC, Carville SF, Smith IC, Rutherford OM, Newham DJ. Strength, power output and symmetry of leg muscle: effect of age and history of falling. *Eur J Appl Physiol* 2007;**100**:553−61.
3. Rubenstein LZ. Falls in older people: epidemiology, risk factors and strategies for prevention. *Age Ageing* 2006;**35**(Suppl 2):ii37−41.
4. Mann WC, Hurren D, Tomita M, Charvat B. An analysis of problems with walkers encountered by elderly persons. *Phys Occup Ther Geriatr* 1995;**13**:1−23.
5. Hambrook GW, Simoneau GG, Bachschmidt RA, Harris GF. Biomechanical effect of changes in walker height and position on sagittal plane elbow dynamics for rehabilitation purposes. *Conf Proc IEEE Eng Med Biol Soc* 1998;**5**:2686−8.
6. Janssen WG, Bussmann HB, Stam HJ. Determinants of the sit-to-stand movement: a review. *Phys Ther* 2002;**82**:866−79.
7. Goldberg A, Chavis M, Watkins J, Wilson T. The five-times-sit-to-stand test: validity, reliability and detectable change in older females. *Aging Clin Exp Res* 2012;**24**:339−44.
8. Whitney SL, Wrisley DM, Marchetti GF, Gee MA, Redfern MS, Furman JM. Clinical measurement of sit-to-stand performance in people with balance disorders: validity of data for the Five-Times-Sit-to-Stand Test. *Phys Ther* 2005;**85**:1034−45.
9. Jonsson E, Henriksson M, Hirschfeld H. Does the functional reach test reflect stability limits in elderly people? *J Rehabil Med* 2002;**35**:26−30.
10. Bohannon RW. Reference values for the five-repetition sit-to-stand test: a descriptive meta-analysis of data from elders. *Percept Mot Ski* 2006;**103**:215−22.
11. Lord SR, Murray SM, Chapman K, Munro B, Tiedemann A. Sit-to-stand performance depends on sensation, speed, balance, and psychological status in addition to strength in older people. *J Gerontol A Biol Sci Med Sci* 2002;**57**:M539−43.
12. Mulder T, Nienhuis B, Pauwels J. Clinical gait analysis in a rehabilitation context: some controversial issues. *Clin Rehabil* 1998;**12**:99−106.
13. Janssen WG, Kulcu DG, Horemans HL, Stam HJ, Bussmann JB. Sensitivity of accelerometry to assess balance control during sit-to-stand movement. *IEEE Trans Neural Syst Rehabil Eng* 2008;**16**:479−84.
14. Doheny EP, Walsh C, Foran T, Greene BR, Fan CW, Cunningham C, et al. Falls classification using tri-axial accelerometers during the five-times-sit-to-stand test. *Gait Posture* 2013;**38**:1021−5.
15. Zijlstra W, Bisseling RW, Schlumbohm S, Baldus H. A body-fixed-sensor-based analysis of power during sit-to-stand movements. *Gait Posture* 2010;**31**:272−8.
16. Regterschot GR, Folkersma M, Zhang W, Baldus H, Stevens M, Zijlstra W. Sensitivity of sensor-based sit-to-stand peak power to the effects of training leg strength, leg power and balance in older adults. *Gait Posture* 2014;**39**:303−7.
17. Mathie MJ, Coster ACF, Lovell NH, Celler BG. Detection of daily physical activities using a triaxial accelerometer. *Med Biol Eng Comput* 2002;**41**:296−301.
18. Yang JY, Wang JS, Chen YP. Using acceleration measurements for activity recognition: an effective learning algorithm for constructing neural classifiers. *Pattern Recogn Lett* 2008;**29**:2213−20.
19. Van Lummel RC, Ainsworth E, Lindemann U, Zijlstra W, Chiari L, Van Campen P, et al. Automated approach for quantifying the repeated sit-to-stand using one body fixed sensor in young and older adults. *Gait Posture* 2013;**38**:153−6.
20. Hwang JY, Kang JM, Jang YW, Kim HC. Development of novel algorithm and real-time monitoring ambulatory system using Bluetooth module for fall detection in the elderly. *Conf Proc IEEE Eng Med Biol Soc* 2004;**1**:2207.
21. Ryan PD, Abigail LL, Gammon ME. Five times sit-to-stand test performance in Parkinson's disease. *Arch Phys Med Rehabil* 2011;**92**:1431−6.
22. Soangra R, Lockhart TE. A comparative study for performance evaluation of sit-to-stand task with body worn sensor and existing laboratory methods. *Biomed Sci Instrum* 2012;**48**:407−14.
23. Seeman TE, Charpentier PA, Berkman LF, Tinetti ME, Guralnik JM, Albert M, et al. Predicting changes in physical performance in a high-functioning elderly cohort: MacArthur studies of successful aging. *J Gerontol* 1994;**49**:M97−108.
24. 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**:M85−94.