CHAPTER III

METHODS

Participants

Female older adults were recruited from several local Chiang Mai elderly centers by direct contact by the researcher. Older adults who were interested in participating in the study were screened for their eligibility by inclusion and exclusion criteria of the study. Eligible participants were classified into the balance-impaired (BI) and non-balance-impaired (NBI) based on the Berg Balance Scale (BBS) (38). The total score of the BBS is 56. Fifteen elderly women with the BBS score less than or equal to 45 were assigned into the BI group, and 15 elderly women with the BBS score more than 45 were assigned into the NBI group.

Inclusion criteria: Persons were included in the study if they

- were aged 60-75 years
- were comprehend instructions and willing to participate in the study
- were able to walk independently without use of assistive device
- had Thai Mini Mental State Exam (TMSE) score 24 or higher (49)

Exclusion criteria: Persons were ineligible for the study if they had been diagnosed with or having

- neurological disorders (e.g. Parkinson’s disease, stroke, brain injury)
- musculoskeletal disorders (e.g. severe edema, severe pain, ulcers, joint inflammation

- severe deformity (e.g. kyphosis, bow leg, knock knee)
- uncorrected visual impairment

Equipment

1. A tri-axial accelerometer (range ± 5 g)
2. A footswitch system (providing external signal)
3. A data logger
4. A video camera
5. A height-adjustable obstacle
6. Reflective markers
7. A MyoDat 6.0 software program
8. A Matlab 6.5 software program
9. A Silicon Coach 6.0 software program
10. A Microsoft Excel 2003 program

Tri-axial accelerometer Footswitch Data logger

Figure 3 Equipment for recording trunk acceleration

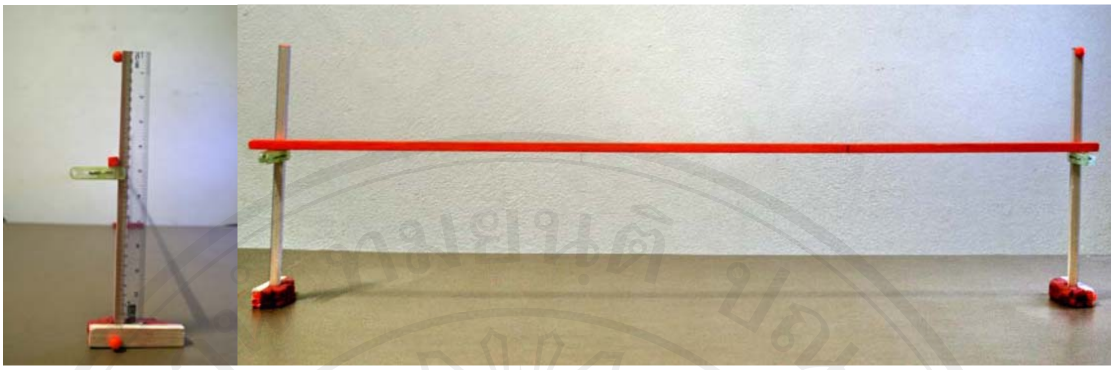


Figure 4 A height-adjustable obstacle

Experimental setup

A height-adjustable obstacle consisted of two upright frames and a 1.00 cm wide x 100.00 cm long wood strip. Two reflective markers were placed on each end of the strip to define the position of the obstacle (50). The strip was light-weight and rigid so it would drop off the frames when contacted. The strip was placed on the two frames with slots spaced in millimeters allowing the obstacle height to be adjusted relative to individual leg length for preventing the influence of the inter-subject anthropometrics differences (50). The obstacle with height-adjustable was used in the study to ensure that older adults of different statue made the same qualitative adaptation in going over obstacles (5). The low and high obstacles were adjusted to be equal to 10% of individual's leg length (10%LL) and 30% of individual leg length (30%LL). These heights were selected corresponding to situations often encountered during daily activities such as walking across a door threshold and stepping up a standard step. The marker were placed in the middle of the floor during the level walking task. The obstacle was placed in the middle of a 10-m walkway during the obstacle gait testing (5, 51). Video camera was placed at a distance of 6 m away from the walking path; parallel to the floor and perpendicular to the plane of motion. Instrument walkway is represented in Figure 5.

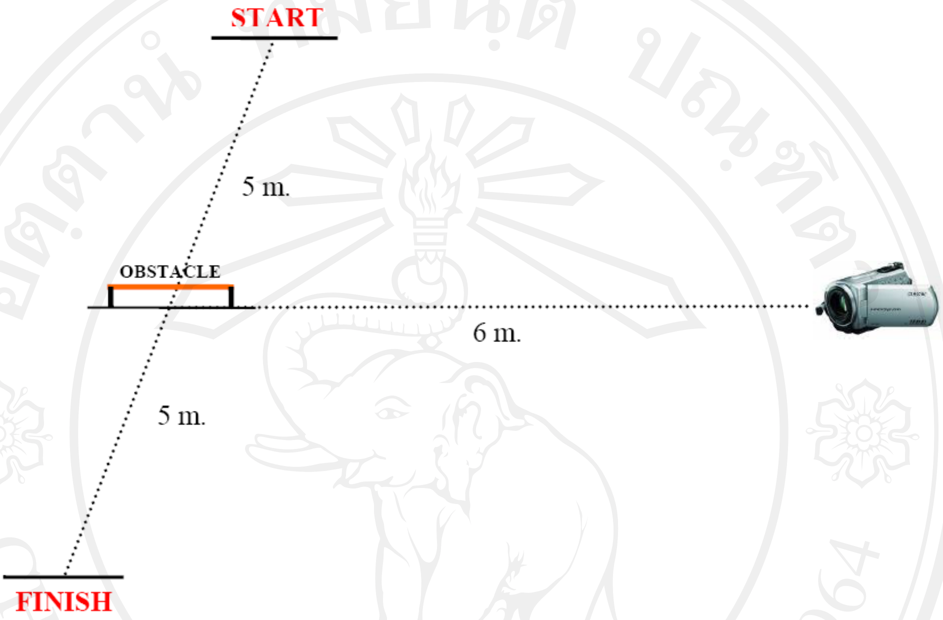


Figure 5 Instrument walkway

Participant preparation

Eligible participants were informed about the purpose of the study and the testing procedure. Each participant read and signed informed consent form in accordance with the Human Experimental Committee of the Faculty of Associated Medical Sciences, Chiang Mai University. Participants completed a health status questionnaire, providing the information on age, residential status, marital status, medical history, self-reported history of imbalance, type of assistive device used for ambulation and prescription medications used (52). Participants were measured for weight, height and leg length. The leg length was measured using the anatomical landmarks, from greater trochanter passed the mid line of knee joint to lateral malleolus (5). In addition to confirm group collection, all participants were asked to perform the Timed up and go test (TUG) (39, 44), a functional balance test, with the instruction “When I ask you to start, I would like you to get up out of this chair and walk at a quick and safe pace to the mark on the floor 3 metres away, turn round and return to the chair and sit down again” to confirm their balance performance.

Prior to data collection, a tri-axial accelerometer had a range of ± 5 g and a footswitch for detecting events of crossing step was attached onto the participant via a custom belt securely placed at a location corresponding to the third lumbar vertebral spinous process (L3) (see Figure 6). Participants wore their own low-heeled walking shoes that they usually wore. Reflective markers were placed on the tip of toe and heel of both shoes to determine foot locations used for calculation of all gait parameters (see Figure 6). Acceleration data of the trunk were sampled rate at 500 Hz using a portable data logger and were later downloaded to a personal computer using a memory card reader for later analysis.

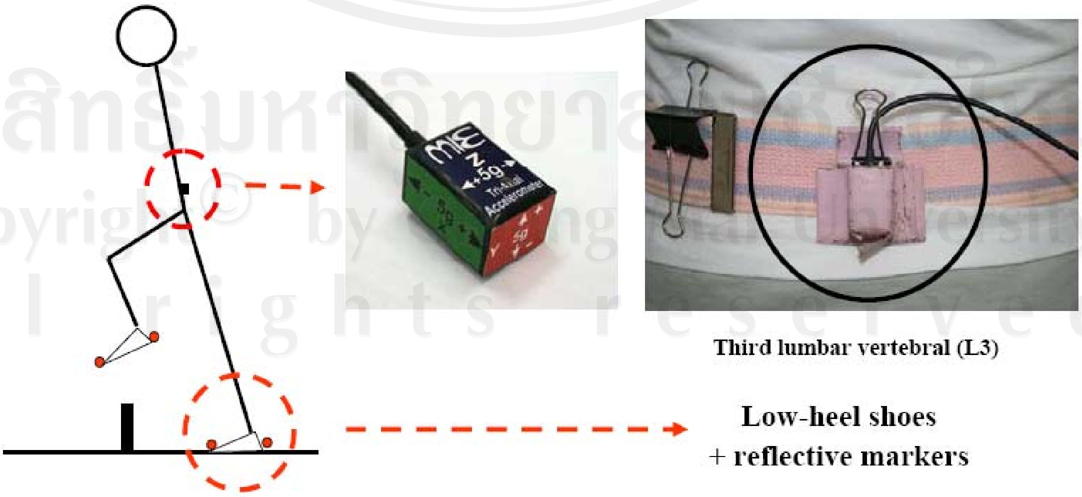


Figure 6 Participant preparation

Testing protocols

All participants were tested in three walking conditions:

Condition 1: Walking on level surface (Level)

Condition 2: Walking and stepping over a low obstacle at a height adjusted to 10% of leg length (10%LL)

Condition 3: Walking and stepping over a high obstacle at a height adjusted to 30% of leg length (30%LL)

For the level condition, each participant was asked to walk at her preferred self-selected walking speed along a 10-m walkway level with the instruction "Please walk straight ahead at your usual comfortable pace and continue walking to the end of walkway before stopping" (53). The researcher pressed a footswitch for providing external signal while the participants walked over the marker on the floor. The external signal provided an event of a swing phase of a gait cycle in the middle of walkway.

For the low and high obstacle conditions, the participant was instructed to walk along the 10-m walkway at a natural walking speed and was asked to step over an obstacle located in the middle of walkway with their preferred self-selected manner with the instruction "Please walk straight ahead at your usual comfortable pace and step over an obstacle in the middle of walkway and then continue walking to the end of walkway before stopping" (53). The researcher pressed a footswitch for providing external signal while the leading limb of the participants crossed the obstacle. The external signal provided an event of a crossing step of leading limb during a crossing stride.

Prior to actual data collection, all participants were given practice for familiarity and safety. Sufficient practice trials (up to three trials) were performed just prior to performing a new obstacle condition. The Level condition was performed first, followed by the low- and high-height conditions, respectively. For the BI group, the averaged obstacle heights were 7.8 ± 0.6 cm and 23.5 ± 1.9 cm for the 10% and 30% conditions, respectively. The corresponding values for the NBI group were 8.0 ± 0.4 cm and 24.1 ± 1.3 cm. All participants performed two trials in each condition with a 2-minute rest between trials and a 5-minute rest between conditions. Data from any trial during which the participant's foot contacted the obstacle was not saved, and additional trial was performed. Two successful trials of each walking condition were selected for further analysis.

Data reduction

- **Peak trunk acceleration amplitude**

Signals of the tri-axial accelerometer and the external signal from the data logger were stored on a memory card, and subsequently transferred to a portable computer for off-line processing by using a MyoDat 6.0 software program. Prior to data analysis, a low pass filter with a cutoff frequency of 30 Hz was applied to the raw trunk acceleration data to reduce noises from electronic and motion artifact (9, 10). According to a method explained by Moe-Nilssen (36, 37, 54), a tri-axial accelerometer positioned over the third lumbar vertebral spinous process (L3) might be tilted due to the curvature of the back, the postural alignment during walking, and inaccuracy in positioning of the instrument. Therefore, the correction for tilting was made for the static gravity component in order to assess true dynamic acceleration using a horizontal–vertical coordinate system and a trigonometric algorithm using a Matlab 6.5 software program (36, 37, 55, 56). The corrected accelerations were transformed to the Microsoft Excel 2003 program for finding peak trunk acceleration amplitude. Diagram of data reduction of trunk acceleration are represented in Figure 7.

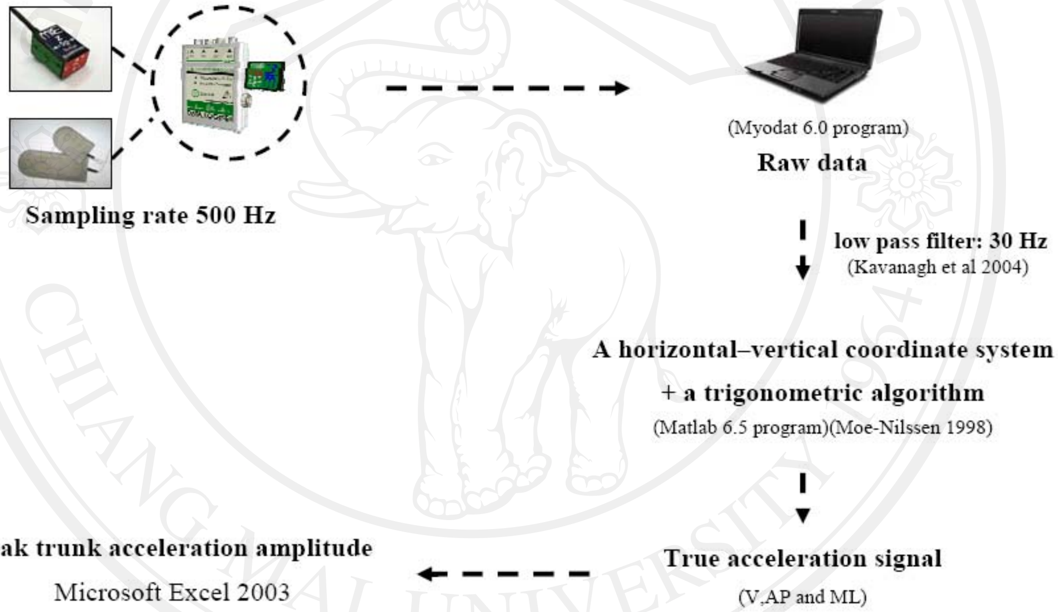


Figure 7 Diagram of data reduction of trunk acceleration

For finding peak trunk acceleration amplitude, peak trunk acceleration amplitude in three directions including vertical, anteroposterior and mediolateral directions were plotted along with the external signal as shown in Figure 8. The highest value of trunk accelerations in each direction in the positive range of trunk acceleration were selected as the peak trunk acceleration amplitudes. Peak trunk acceleration amplitudes during a crossing stride of the two successful trials from each walking condition were averaged.

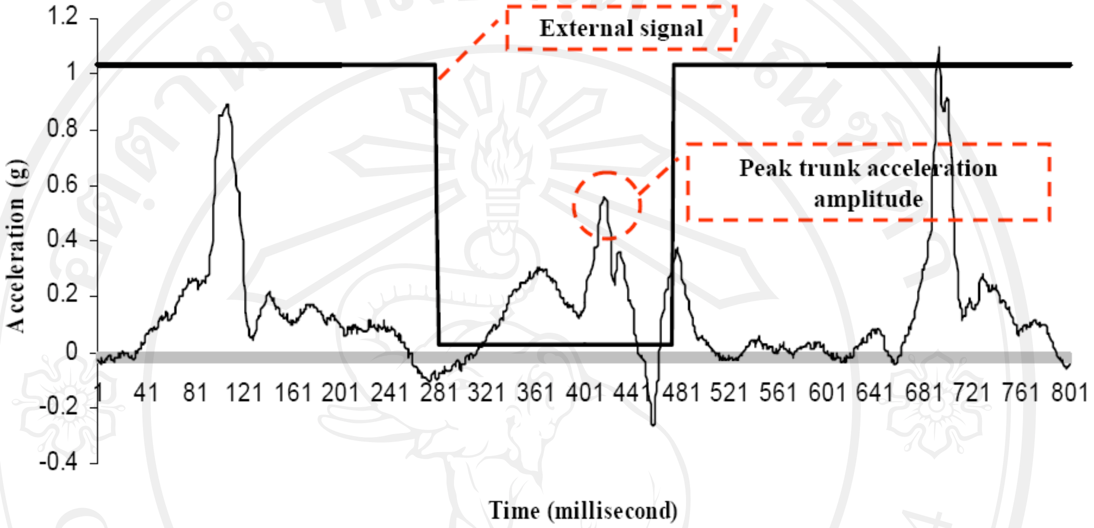


Figure 8 Selection of peak trunk acceleration amplitude

- **Gait parameters**

Gait parameters of the level walking and walking over an obstacle tasks were analyzed from the two-dimensional (2D) coordinates of the markers placed on shoes. All video images of the successful walking trials were imported to a computer installed with a Silicon Coach 6.0 program (Silicon Coach Ltd., Dunedin, New Zealand). Video images were captured and digitized to obtain the x-y coordinates for each reflective marker using a Silicon Coach 6.0 program with a sampling rate at 50 frames per second. The video image from each walking condition was digitized separately in three frames for collected gait parameters of level walking and gait parameters of crossing step. Diagram of data reduction of gait parameters are represented in Figure 9. All gait parameters of level walking and crossing step were defined as the distance in term of centimeter (cm). All digitized frames were transferred to ratio scale for calculation using a Microsoft Excel 2003 program.

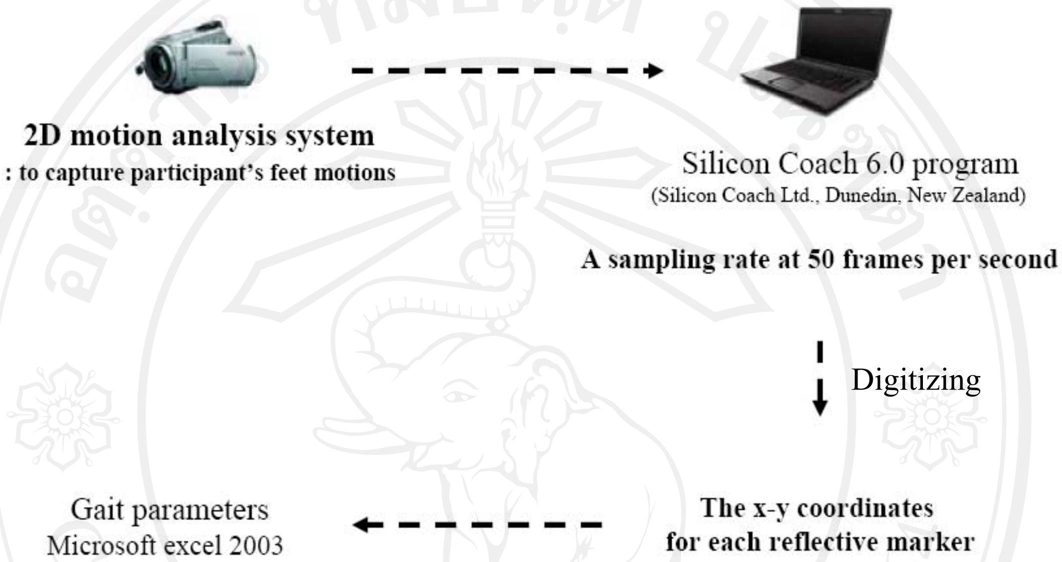


Figure 9 Diagram of data reduction of gait parameters

Gait parameters of level walking

Gait parameters of level walking included walking speed, step length and toe-floor clearance.

- **Walking speed** (m/s) was defined as the rate of distance of walking per time (57).
- **Step length** (cm) was defined as the distance from between successive foot-floor contacts with opposite feet (57).
- **Toe-floor clearance** (cm) was defined as the maximal toe clearance from the floor where the reflective markers placed on the tip of longest toe at mid wing phase just prior to terminal swing phase (58).

Gait parameters of crossing step (Figure 10)

Gait parameters of crossing step included crossing speed, crossing step length, leading and trailing limb elevations and pre- and post-obstacle distances.

- **Crossing speed** (m/s) was defined as the rate of change of distance per time that the leading and trailing limbs completely spend to cross the obstacle (58).
- **Crossing step length** (cm) was defined as the horizontal distance from the heel marker of trailing limb to the heel marker of leading limb (58).
- **Leading limb elevation** (cm) was defined as the vertical distance between the toe marker of the leading limb and the floor when the toe was directly above the obstacle (7).
- **Trailing limb elevation** (cm) was defined as the vertical distance between the toe marker of the trailing limb and the floor when the toe was directly above the obstacle (7).
- **Pre-obstacle distance** (cm) was defined as the shortest horizontal distance between the toe marker of the trailing limb and the obstacle (58).
- **Post-obstacle distance** (cm) was defined as the shortest of the horizontal distance between the heel marker of the leading limb and the obstacle (58).

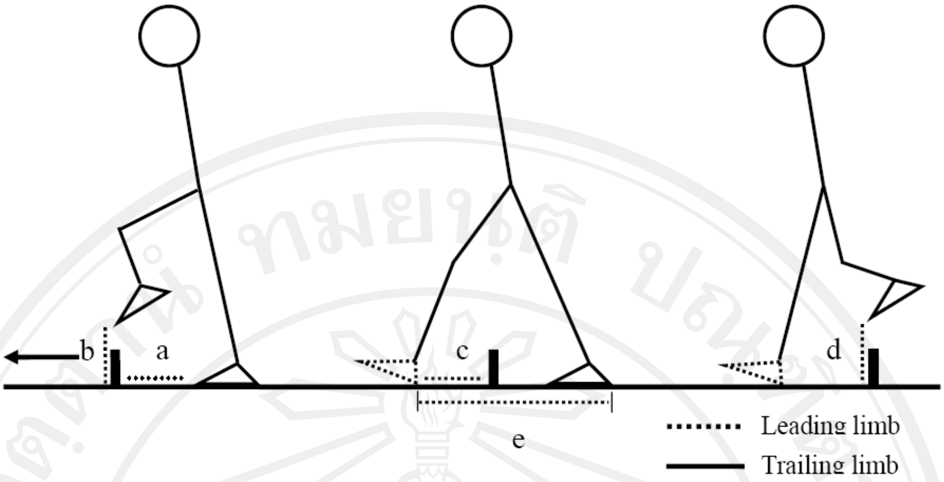
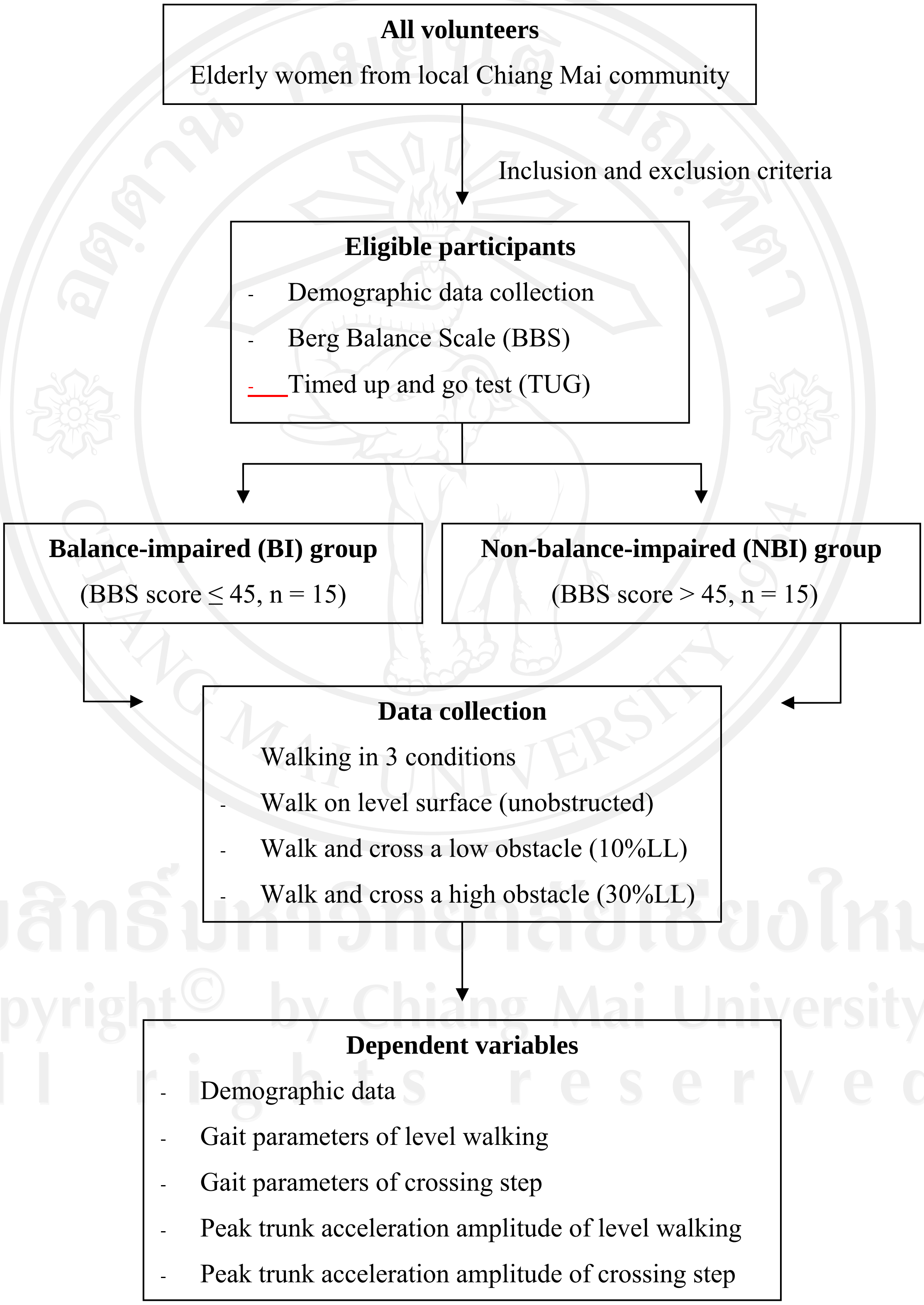


Figure 10 Illustration of the gait parameters of crossing step (a) pre-obstacle distance, (b) leading limb elevation, (c) post-obstacle distance, (d) trailing limb elevation and (e) crossing step length

Figure 11 Diagram of data collection procedures



Reliability of measurements

Before the formal data collection, a pilot study was conducted in 10 healthy elderly subjects for determining reliability of the measured variables. Peak trunk acceleration and gait parameters were obtained following the protocols used for actual test. Subjects in a pilot study were tested twice within 2 days. Intra-tester reliability was determined using intra-class correlation coefficients (ICCs). ICCs values of peak acceleration amplitude of trunk and gait parameters of three walking conditions in this study ranged from 0.78-0.97. More detail was in Appendix F.

Statistical analysis

Data were tested for normality using Shapiro-Wilk test. For group comparison of variables pertaining to the level walking condition, if group data were parametric independent samples t-test was used and if data were non-parametric data Mann-Whitney U tests was used.

For variable related to the obstacle crossing task, a 2 (group) x 2 (obstacle height) analysis of variance mixed model with obstacle height as a within-subject factor and group as a between-subjects factor was performed to determine the differences between the two groups for peak trunk acceleration amplitude and gait parameters of a crossing step during the stepping over an obstacle tasks (low and high). A level of significance for all variable were set at $p<0.05$. Statistical analyses were undertaken using the Statistics Package for Social Sciences (SPSS version 10.0 for Windows, SPSS, Inc., Chicago).