CHAPTER 1

Introduction

1.1 Rationale

Gait assessment is a powerful tool to assess many facets of health in older adults. Spatiotemporal gait parameters can provide valuable information regarding overall health (1), falls status (2), cognitive performance (3), quality of life (4), and mortality rate (5). Maki (2) examined the association between spatiotemporal measures and the likelihood of future falls and fear of falling. The results showed that increased stride width was associated with both falls history and fear of falling. Hardy et al. (5) determined the association between 1-year improvement in gait speed and 8-year survival in older adults. The results showed that an improvement in gait speed at 1 year strongly predicted mortality. The mortality rate was 31.6% in 1-year improvers (improved at least 0.1 m/s at 1 year follow-up) compared with 49.3% in never improvers. Thus, gait characteristics can be a useful clinical indicator of health status in older adults.

Most assessment tools used for gait analysis include optoelectronic motion capture systems, force plates, and instrumented walkways (e.g. GAITRite) (6-8). These instruments are often used in a controlled laboratory environment and provide high accuracy. However, they are bulky, expensive, difficult to use, and require sufficient time for setup and analysis. Furthermore, these tools are not available in all clinical settings. A major limitation is the inability of these tools to measure gait data across more than a few steps and do not naturally assess walking performance in a home-based environment. Nonetheless, due to their high reliability and validity, these devices are frequently used as a gold standard for gait (9, 10).

Recently, tri-axial accelerometers have been widely used in gait analysis as an alternative to the laboratory assessments. Not only can they accurately quantify spatiotemporal gait parameters, but they also have a number of advantages, including a lower cost, portability, and ease of use. Furthermore, accelerometer-based devices can be used to collect data from many gait cycles and allow measurements in a more challenging context (11-13). Previous studies have shown that body-worn accelerometers are valid for the assessments of spatiotemporal gait characteristics. Hartmann et al. (14) examined the concurrent validity of a trunk tri-axial accelerometer system (DynaPort®MiniMod) with a pressure-sensing walkway (GAITRite) for spatiotemporal gait parameters at preferred, slow, and fast self-selected walking speed in older adults. The tri-axial accelerometer was placed at the lower back area (a reference point close to the body’s center of mass), since this location closely reflects actual lower trunk accelerations during human walking (15). The results showed that the concurrent validity was excellent for walking speed, cadence, step duration and step length (intraclass correlation coefficients between 0.99 and 1.00, ratios limits of agreement between 0.7% and 3.3%) (14). However, accelerometer-based systems have a number of disadvantages. First, they are usually attached directly onto the body (e.g. trunk, wrist, ankle) which can lead to discomfort among the elderly. Second, elderly often have problems with memory and recall, thereby reducing compliance. Lastly, the cost of commercial software packages are relatively high (16, 17). These limitations can be resolved with the use of smartphones.

Nowadays, the use of smartphones has become ubiquitous even among the elderly, thereby allowing for a cost-effective, easily deployable method for assessing a person’s gait. Open source tools are also readily available, allowing for ease of smartphone application development and deployment, thus reducing the cost of purchasing expensive software package (18-20). Furthermore, instead of attaching accelerometers onto a user's body, a smartphone device can be engaged in the user's hands, pockets, purse, or backpack, thereby reducing any discomfort. In addition, compliance problems can be resolved as people already use smartphones on a daily basis. Thus, the use of smartphones to measure gait has become a practical and popular goal due to its lower cost, accessibility, convenience, and portability.

Kim et al. (21) determined the concurrent validity of a smartphone-enabled camera-based system (SmartGait) with the GAITRite system for measurement of spatiotemporal gait parameters at preferred, slow, and fast walking speed in healthy young adults. The gait assessment was based on the video recording from a smartphone camera. The results showed that all gait parameters (i.e. step length, step width, step time, gait speed, double support time and their variability) had modest to excellent agreements (ICCs between 0.731 and 0.982) between the two systems at all speeds. In addition, Furrer et al. (22) examined the intra-session reliability as well as concurrent validity of the smartphone-based accelerometer for the quantification of level walking in healthy young adults. The vertical center of mass (CoM) displacement and duration derived from the smartphone built-in accelerometer were compared to those from the marker-based motion capture system. The results showed good to excellent reliability (ICCs between 0.71 and 0.80) for spatial parameters (i.e. CoM displacement from left to right, as well as from the lowest to the highest CoM position during a left and right step) and fair to excellent reliability (ICCs ranged from 0.49 to 0.86) for temporal variables of smartphone measurements. All variables correlated significantly with measurements of the motion capture system with moderate correlation (Pearson r between 0.61 and 0.68) for spatial parameters and moderate to strong correlations (Pearson r ranged from 0.62 to 0.92) for temporal variables.

Additionally, varying the placement of a smartphone-based accelerometer on the body (i.e. wrist, ankle) or on the individual's attire (i.e. hands, pockets, purse, or backpack) has been found valid for assessing the type of activity an individual is performing. Antos et al. (23) investigated the accuracy of activity tracking using a smartphone-based accelerometer when placed at four locations (i.e. hand, belt, pants pocket, and bag) while performing five activities (i.e. sitting, standing, walking, and transitions between sitting and standing). The results showed that both the activities and phone locations can be accurately predicted using the smartphone built-in accelerometer, with 88% accuracy for activities and 96.4% accuracy for phone locations.

To our knowledge, however, the ability to assess spatiotemporal gait parameters based on a smartphone-based accelerometer is unknown. Since people carry phones differently in everyday life, the effects of varying placement of a smartphone on the body or attire while assessing spatiotemporal gait parameters also needs to be investigated. Hence, the aims of this study are 1) to assess the validity of a smartphone-based tri-axial accelerometer in determining gait characteristics including gait velocity, step length, and step time; and 2) to assess the validity of a smartphone-based tri-axial accelerometer in determining gait characteristics when attached to the body as well as when placed in a bag, belt, hand, and pocket. Reference values for gait parameters were obtained from a GAITRite instrumented walkway.

1.2 Purposes of the study

1.2.1 To assess the validity of a smartphone-based tri-axial accelerometer in determining gait characteristics including gait velocity, step length, and step time.

1.2.2 To assess the validity of a smartphone-based tri-axial accelerometer in determining gait characteristics when attached to the body as well as when placed in a bag, belt, hand, and pocket.

1.3 Hypotheses of the study

1.3.1 A smartphone-based tri-axial accelerometer would demonstrate high to very high concurrent validity with GAITRite for all gait parameters.

1.3.2 The greatest validity would be demonstrated while the smartphone was attached to the body and on a belt wrapped around the waist. Due to extraneous movements detected while the smartphone is in a bag, hand, or pocket, we expected lower validity of spatiotemporal gait parameters from these conditions.