ELSEVIER

Physiotherapy 101 (2015) 266–272

Physiotherapy

Systematic review

Interactions of sex and aging on spatiotemporal metrics in non-pathological gait: a descriptive meta-analysis

Rebecca Frimenko [a], Charles Goodyear [a], Dustin Bruening [b,*]

[a] Infoscitex: a DCS Company, 4027 Colonel Glenn Highway, Suite 210, Dayton OH 45431-1672, United States
[b] Air Force Research Laboratories, 2800 Q Street, Building 824, Wright-Patterson AFB OH 45433-7947, United States

Abstract

Background Individual studies examining aging-related changes in gait offer conflicting information on differences between male and female spatiotemporal metrics over the course of a mature lifetime. Furthermore, these studies do not often account for a known difference in size between men and women, and thus may reach conclusions based upon size rather than sex differences.

Objective To examine the influences of sex, height, and age on spatiotemporal metrics during non-pathological gait over the course of adult aging.

Data sources Potentially relevant articles were identified from PubMed, Web of Science, and Google Scholar using the key words 'gait,' 'walk', 'gender,' 'sex,' 'female,' 'male,' 'gait speed,' 'step length,' and 'cadence.'

Eligibility criteria (1) article could be obtained in English, (2) contained information about non-pathological subjects, (3) analyzed kinematics of walking, (4) provided female and male data, (5) average female/male age difference not more than 5 years, (6) reported a measure of variance and number of subjects, and (7) no known retractions associated with the publication.

Results and conclusions Non-dimensional gait speed analysis suggests that gait speed differences between men and women may be an artifact of size rather than sex. In both raw and dimensionless data, this analysis indicates that men may take longer step lengths than women, and women may have a higher cadence than men. This analysis also identified a possible increase in many metrics between 20 and 40 years of age, before decreasing around the fifth decade of life. Future studies should examine these trends across the entire lifespan.

Published by Elsevier Ltd on behalf of The Chartered Society of Physiotherapy.

Keywords: Gait; Sex; Gender; Aging; Normalization

Introduction

Age related declines in physical mobility represent a major health concern, particularly as the developed world's mean age continues to rise. Of all measurable mobility parameters, spatiotemporal gait metrics are reported and described most often. These variables are easily obtainable and, more importantly, have been found to correlate with pathologies, injury outcome, and rehabilitation [1,2]. Decreases in gait speed, cadence, and step length have been associated with higher incidences of loss of function, injury, and frailty [3,4]. Because of the efficacy of these metrics in quantifying trends, identifying at-risk patients, and influencing treatments, they are often advocated as screening tools for early intervention among the elderly [5].

Just as the etiology of many pathologies affecting older adults reflects differences between men and women (e.g. Parkinsons's disease [6,7], diabetes [8,9], and low back pain [10,11]), gait metrics are often examined for differences between sexes. For example, males have been shown to walk at higher preferred speeds, with longer step lengths, but reduced cadence compared with women [12,13]. While several studies have suggested that these spatiotemporal metrics deteriorate more rapidly with increasing age for women than men [14–17], others have found no sex interactions

* Correspondence: Tel.: +1 937 255 5272.
E-mail addresses: rebecca.frimenko.ctr@us.af.mil (R. Frimenko), charles.goodyear.1.ctr@us.af.mil (C. Goodyear), dustin.bruening.1@us.af.mil, dabruening@gmail.com (D. Bruening).

http://dx.doi.org/10.1016/j.physio.2015.01.003
0031-9406/Published by Elsevier Ltd on behalf of The Chartered Society of Physiotherapy.

during aging [18–21]. Most individual studies, due to practical constraints, examine a subset of the aging process, choosing to compare two age groups (e.g. old and young) or select decades (e.g. 60 to 80 year olds) rather than the entire course of mature aging. As a result, the overall description of changes in gait due to aging, and how the sexes age differently, has not been clearly established. Furthermore, these metrics are not often normalized, though differences attributed to sex may in fact be a reflection of known disparities in height or leg length [17].

Because spatiotemporal metrics are easily acquired, there is a wealth of data available in published literature which may be mined and analyzed as a collective group to help clarify these limitations in existing literature. The purpose of this analysis, therefore, was to integrate data from previously published studies in order to examine the influences of sex, height, and age on spatiotemporal metrics during non-pathological gait over the course of adult aging.

Methods

Potentially relevant articles were identified with an electronic search of PubMed, Web of Science, and Google Scholar using combinations of keywords 'gait,' 'walk,' 'gender,' 'sex,' 'female,' 'male,' 'gait speed,' 'step length,' and 'cadence.' Article abstracts from all searches were reviewed independently by two experienced biomechanists (5 and 15 years of experience) for relevance regarding three metrics: preferred speed, cadence, and step length. Articles were compared against these inclusion criteria: (1) the article was written or could be obtained in English, (2) the article contained information about non-pathological subjects, (3) the study analyzed kinematics of walking, (4) the article provided a means of comparing both sexes, (5) the study included data for adult subjects of at least 20 years of age, (6) the average age difference between female and male subjects was not more than 5 years, (7) the study reported mean, standard deviation (or standard error of the mean), and number of subjects, and (8) no known retractions or inaccuracies associated with the publication. Additional papers were identified from cited references and evaluated against the inclusion criteria.

Because there was no single keyword which could narrow responses (e.g. searching for a specific pathology or age range), a large number of articles was returned for each search. The inclusion criteria could only be satisfied through manual review, and an iterative search process of database searches, manual review, and further exploration of cited works from the relevant articles was used to build the catalog of references for this study. For example, using the search ((gait) OR (walk*)) AND ((sex) OR (gender)) AND (female) AND (male) AND (((speed) OR (velocity)) OR (step length) OR (cadence)) in PubMed yielded 895 articles, eight of which completely fit the inclusion criteria. The references from each of these articles as well as the lists of articles which cited the identified studies were examined for possible inclusion. This process was repeated, using all three search engines and numerous key word combinations, until the yield of new articles ended.

From each selected article, means and standard deviations for gait speed, step length, and cadence were extracted for each sex and tabulated along with means of age and height for each group. If a range of ages were given (e.g. 20 to 29 years old), a median value was taken as the given age. Initially, each data point was plotted against age. A within-study difference between female and male values at each age was also calculated and plotted as a scatter against age.

A measure of central tendency was desired in order to assess differences in sex and trends with increasing age. For each gait metric, means within each sex at 10-year age bins were used to obtain Cochran's Q-value [22]. These Q-values indicated that means were not homogeneous and, therefore, should not be combined in to an overall mean for each sex and age bin. Instead, a qualitative approach was chosen wherein a curve fitting procedure was used to visualize differences in sex and aging. Following a method developed by Yao *et al.* [23], a predicted value was determined for each sex at each age where data was reported [Eq. (1)]. This predicted value was determined using a weighted least squares regression model, for each unique age separately, where y_i was the metric for study i, B_0 the intercept and predicted value for ages equal to A_j, B_1 the slope, A_i the age of each data point, and A_j the age for the predicted value. Ages closer to A_j were weighted, according to a Standard Normal density function, more heavily than farther away [Eq. (2)]. The standard deviation (SD) used in the weight function was initially set at 5 years and then increased until the smoothness of the curve stabilized at a standard deviation of 10 years. As a final step, the predicted values across age for each sex were connected to form the curve. For each $j = 1,\ldots,$ number of unique ages

$$y_i = B_0 + B_1^*(A_i - A_j) \quad i = 1, \ldots, \text{ number of studies} \quad (1)$$

$$\text{weight} = f(z_i) \sim N(0, 1) \text{ where } z_i = \frac{A_i - A_j}{\text{std}} \quad (2)$$

Studies which contained all three metrics and height data formed a subset of the initial dataset, allowing for comparison between cadence, step length, and gait speed, as well as height normalization. Data normalization was performed on this subset according to the method described by Hof [24] which resulted in dimensionless data for gait speed, step length, and cadence.

Results

All data

The inclusion criteria was satisfied by 41 articles [1,10,13–15,17–20,25–57]. From these articles, 95