THE ROLE OF PHYSICAL ACTIVITY IN CHANGES IN WALKING MECHANICS WITH AGE

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INTRODUCTION
The growth of the aging population has produced an increased need to identify factors that contribute to the ability of the aged to maintain an active and independent lifestyle. Gait impairments are important determinants of relative functional independence for the aged and the degree of mobility that is maintained through the aging process. The underlying mechanisms for alterations in walking performance in the aging population are unclear, but may include changes in muscle strength, balance, joint mobility and cardiovascular fitness. Walking interventions have shown a benefit for minimizing gross functional deficits in the aged [1]. However, the role of reduced or increasing habitual activity in changes in ambulatory mechanics associated with aging is unclear.

The reported changes in gait and physical function might be attributable to a decrease in strength and flexibility of selected muscle groups related to aging [3] but these may also be exacerbated by a decline in fitness and physical activity. Thus, while functional decline in the aging population may be a significant factor in limiting physical activity and independence, decreases in habitual activity independent of functional status may be a confounding factor in this analysis.

Therefore, the purpose of this study was to investigate the effects of aging, in the absence of reduced physical activity on walking mechanics. This study tested the hypothesis that: self-selected walking speeds, cadence and sagittal plane hip, knee and ankle kinematics and kinetics will not be associated with age in highly active older adults.

METHODS
Gait mechanics and habitual walking totals were quantified for 214 healthy older adults recruited as part of a larger study [8]. All subjects were healthy with a body mass index of less than or equal to 30 kg/m², had no self-reported history musculoskeletal deficits and indicated walking was their primary form of physical activity. Gait data were also collected for 24 healthy active young adults. Volunteers provided informed consent prior to participation per Stanford University IRB guidelines.

Steps per day were measured using an activity monitor (AMP231/331 Dynastream Innovations Inc. Canada) worn for five days. Only older subjects (133 from the original 214), with a daily average of ≥7500 steps/day were included in the analysis. Motion data were collected with an optoelectronic system (Qualysis Inc., Sweden). Subjects walked on an 11m long walkway with an embedded force plate (Bertec Inc, OH, U.S.A) at three self-selected speeds of slow, normal and fast while three-dimensional kinematic and force data were collected. Force and motion data were captured synchronously at 120Hz. An inverse dynamics approach was used to calculate external moments at the hip, knee and ankle. GRFs were normalized to body-weight and joint moments were normalized to BW x height to reduce variance between the groups. External joint moment and GRF data were normalized to a walking speed 1.3 m/s (normal) and 1.6 m/s (fast) using linear regression models with data from all walking trials (slow, normal and fast) for each subject.

Statistics:
Linear regression was used to test for an association between age and the following outcomes: walking speed, cadence, flexion angles at touch-down and toe-off and the maximum and minimum flexion/extension joint moments for the hip, knee and ankle.

RESULTS
Self-selected walking speed was not associated with age (r² = 0.007; p =0.291). Cadence at the self selected walking speed was significantly correlated with age, the association was strong when cadence was normalized for walking speed (at 1.3 m/s r² = 0.297) (Figure 1).

Figure 1: Walking speed(lt), and cadence(rt) as a function of age. The age-cadence relationship indicates a 1.9 steps/min increase in cadence per decade.

Weak, while significant, associations between age and the ankle angles at heel-strike and toe-off were found. (Figure 2). There was a trend for greater knee flexion at both heel-strike (r² = 0.019; p=0.086) and toe-off (r² = 0.024; p =0.052) with increasing age.

Again at 1.3 m/s significant, but weak, associations between age and the peak hip flexion (p< 0.001; r² =0.076) and
extension (p = 0.005; $r^2 = 0.05$) moments were found. At this speed there were no associations between age and the knee flexion or extension moments or the ankle dorsiflexion moment (Figure 3). At a faster speed (1.6 m/s) significant or trends for associations between all sagittal plane joint moments and age were found (Figure 3).

Figure 3: Joint kinetics as a function of age. The kinetics were normalized to walking speed of 1.3 m/s (blue) and 1.6 m/s (green)

DISCUSSION
The results of this study indicate that the active (>7500 steps/day ~ 6km/day) middle age and older adults do not have the same reduced walking speeds reported in previous studies that included subjects with a range of activity levels [3,4,9]. The results also indicate that the subjects in this study increased cadence with age to maintain normal walking speed thus compensating for a shorter step length. The slower walking speeds previously reported for healthy elderly subjects have been attributed to a reduced stride length [2] and suggested as a limiting factor for maintaining normal walking speed. Thus, a reduced step-length with age can be compensated for with increases in cadence in active older subjects. However, it does appear that reduced stride length is common to aging irrespective of activity level.

The reduced stride length likely influenced the ankle joint range of motion, the peak external ankle dorsi-flexion moment and the increases in the hip flexion and extension moments with increasing age. However these associations were weak (small $r^2$) indicating that age in this highly active group plays only small role in the variance in the walking mechanics. The magnitudes of changes found with age were smaller than previously reported [2]. At the faster speed, a 5% difference in the ankle dorsi-flexion moment was noted between the youngest and oldest subjects, a difference of 25% was reported previously by Devita et al.[2]. This suggests the reported effects of age on gait mechanics in the literature may be exacerbated by declines in physical activity that often accompany age.

Walking with an increased cadence, allows the legs to be more vertical and thus changes the relative mechanical demand on the lower extremity muscle groups[10]. These changes in walking strategy may reflect an adaptation to a reduction in the capacities of the muscle tendon units (MTU) with age, in particular the plantar-flexors, occurring even in these highly active older subjects. The fact that the reduced stride length seems common even in this active group also suggests that neurological changes associated with age may require shorter strides for stability. The adaptations in walking mechanics with age although small were more prevalent at the faster walking speed. Although active older individuals can increase cadence to a certain level to accommodate a possible decrease in stability and strength, at faster walking speeds this becomes more challenging requiring greater adaptations in walking mechanics.

CONCLUSIONS
These results suggests that aging alone may have only a small impact of adaptations in ambulatory function and that decreases in physical activity with age may play an important role in the previously observed adaptations in ambulatory function in older adults. The presented results support the use and promotion of walking based activity interventions for maintaining functional capacities and independence with age.

ACKNOWLEDGEMENTS VA Merit Review project A2592R. Special thanks to Christy Dairaghi, Barb Elspas, Joe Guerricabeitia, Jonathan Rylander

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