Gait & Posture 59 (2018) 128–133

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Full length article

The association between habitual walking speed and medial femoral cartilage deformation following 30 minutes of walking

Matthew S. Harkey[a,*], J. Troy Blackburn[b], Hope Davis[b,c], Leslie Sierra-Arévalo[b], Daniel Nissman[d], Brian Pietrosimone[b]

[a] Division of Rheumatology, Tufts Medical Center, Boston MA, United States
[b] Department of Exercise and Sports Science, University of North Carolina at Chapel Hill, Chapel Hill NC, United States
[c] Human Movement Science Curriculum, University of North Carolina at Chapel Hill, Chapel Hill NC, United States
[d] Department of Radiology, School of Medicine, University of North Carolina at Chapel Hill, Chapel Hill, NC, United States

ARTICLE INFO

Keywords:
Cartilage thickness
Loading
Ultrasound
Knee
Gait
Body mass index

ABSTRACT

Habitual walking speed is a key functional outcome that has implications for knee biomechanics that occur during gait. Lower extremity biomechanics during walking affects the loading of the femoral cartilage. Ultrasonography (US) can be used to assess resting femoral cartilage thickness and acute cartilage deformation in response to walking. The purpose of this study was to determine the association between habitual walking speed and both resting femoral cartilage thickness and deformation. Twenty-four healthy participants with no history of knee injury volunteered for this study. Habitual walking speed was assessed with a 20-m walk test. Femoral cartilage thickness was assessed with US in the medial condyle, lateral condyle, and intercondylar regions prior to and immediately following 30 min of walking. Femoral cartilage deformation was calculated as the percent change in cartilage thickness acutely following the walking protocol. Separate Pearson product moment correlations were used to assess the association between habitual walking speed and each US cartilage variable. Slower habitual walking speed was significantly associated with greater medial femoral cartilage deformation ($r = 0.48$, $P = 0.018$), but not with lateral and intercondylar deformation. Habitual walking speed was not significantly associated with the resting cartilage thickness in any cartilage region. These findings highlight the *in vivo* association between walking speed and medial femoral cartilage deformation. When controlling for body mass index, the association between walking speed and medial cartilage deformation was weakened ($\Delta r = -0.12$). Future studies are needed to determine the extent to which BMI influences the association between walking speed and cartilage deformation.

1. Introduction

Walking speed has been described as a key functional outcome, as slower walking speeds are predictive of disability in activities of daily living [1] and mortality [2] in older individuals. In healthy individuals, habitual walking speed is consistent until approximately age 62, after which walking speed declines by 12–16% per decade [3]. In individuals with knee osteoarthritis (OA), slower walking speed predicts disease progression [4] and the likelihood of joint arthroplasty [5]. Thus, walking speed is recommended as a simple, clinically assessable performance measure in individuals with OA to assess functional limitation [6]. Slower walking speed alters walking biomechanics that may influence how knee cartilage is loaded [7]. However, it is not understood if individuals will permanently slow their walking speed due to changes in the cartilage structure, or if persistent slower walking speed alters cartilage loading and creates permanent changes in cartilage structure. Therefore, further understanding of how walking speed influences healthy cartilage is imperative to understand the unhealthy cartilage response in pathological populations.

Walking speed is a simple functional outcome that can be easily included into routine clinical testing [6], and is correlated with more sophisticated measures of lower extremity biomechanics [8–10]. Specifically, faster walking speed is associated with greater magnitude [8,9] and rate [10] of the vertical ground reaction force (vGRF) during the loading phase of gait, and greater tibial acceleration at heel strike [11]. Conversely, slower walking speed results in greater magnitude of the vGRF during the mid-stance of gait [8,9] which when coupled with a prolonged stance phase, may result in greater loading throughout the

* Corresponding author. correspondence and reprint requests to: M. Harkey, Division of Rheumatology, Tufts Medical Center, 35 Kneeland St. 4th Floor Boston, MA 02115, United States.
E-mail address: mharkey@tuftsmedicalcenter.org (M.S. Harkey).

http://dx.doi.org/10.1016/j.gaitpost.2017.09.039
Received 5 May 2017; Received in revised form 26 September 2017; Accepted 28 September 2017

entire gait cycle. Therefore, alterations in walking speed have varying effects on lower extremity loading depending on the specific phase of the gait cycle, which suggests that the greater impulsive loading of faster walking or greater prolonged loading of slower walking may disparately affect both the structure and deformational behavior of knee cartilage [12,13].

Due to the repetitive nature of walking, healthy knee cartilage structure is theorized to adapt to the biomechanical loads applied during this common activity of daily living [12]. While MRI is the current gold standard for *in vivo* knee cartilage imaging, ultrasonography (US) has emerged as a valid and reliable technique to assess femoral cartilage thickness [14]. Additionally, US allows for a quick, clinically accessible option that may allow for more routine cartilage structure assessments. However, no investigations have determined if a clinical measure of walking speed is associated with resting femoral cartilage thickness. While resting cartilage thickness provides information about cartilage structure, this measure does not provide insight regarding the composition or function of the cartilage. The earliest stages of OA result in compositional tissue changes (e.g. proteoglycan disruption, type II collagen disorganization, increased water content) that occur prior to overall declines in cartilage structure [15]. Disruption in cartilage composition may alter the cartilage water content [16]. which will lead to a decreased ability of the cartilage to resist impulsive loading that leads to increased cartilage deformation. Thus, the extent of cartilage thickness deformation acutely following activity is theorized to provide a surrogate assessment of cartilage composition, as cartilage deformation is governed by the composition of the structure [13]. MRI and US are capable of quantifying acute femoral cartilage deformation following bouts of walking [17,18], running [18,19], and drop-landing [19]. However, no investigation has determined how walking speed affects acute femoral cartilage deformation.

In order to successfully identify a pathological relationship between cartilage structure/deformation and walking speed in individuals at risk for OA development, it is necessary to initially establish how habitual walking speed in healthy individuals is related to resting cartilage thickness and cartilage deformation following walking. Therefore, the purpose of this study was to determine the association between a clinical measure of habitual walking speed and US measured: 1) resting femoral cartilage thickness and 2) acute femoral cartilage deformation following 30 min. We hypothesized that slower walking speed would be associated with thicker resting femoral cartilage thickness and greater cartilage deformation.

2. Methods

2.1. Design

In this cross-sectional study, femoral cartilage thickness was determined at rest and following 30 min of treadmill walking in healthy individuals. Additionally, habitual walking speed was assessed with a 20-m walk test. Participants were instructed to limit their physical activity to their usual activities of daily living prior to reporting to the laboratory on the day data collection occurred. The time of day in which data collection occurred was not controlled between participants.

2.2. Participants

We recruited a convenience sample of twenty-four healthy individuals between the ages of 18 and 35 years who self-reported participating in physical activity for at least 20 min 3 days per week. Additionally, the participants reported no history or symptoms of OA, lower extremity surgery, or ligamentous knee injury in the 6 months prior to participation. Based on a previous investigation that determined the association between a specific biomechanical variable of medial knee loading and cartilage deformation [20], we estimated that there would be a moderate association between cartilage deformation and walking speed (r = 0.5). Therefore, we determined (G*Power v.3.1.9.2) that 23 participants would be needed in order to detect a statistically significant moderate association with 80% power and an alpha level of 0.05. The study was approved by the biomedical Institutional Review Board at the University of XXXXXX, and all participants provided written informed consent prior to participation.

2.3. Data collection procedures

2.3.1. Twenty-Meter walk protocol

Participants began the data collection session by performing three trials of a timed 20 m walk at their habitual walking speed [21,22]. Participants were instructed to walk at a speed that would reflect how they would “comfortably walk down the sidewalk” throughout the entire 20 m trial. Timing of each trial began when the participant took their first step at the starting line and ended when they passed through the 20 m finish line. The time needed to complete the 20 m walk was determined with a stopwatch, converted to walking speed (i.e. m/s), and averaged across the three trials. Participants were instructed not to decelerate at the finish line but to maintain their speed through the entire 20 m distance and decelerate in the ample space provided past the finish line.

2.4. Ultrasonographic assessment of the femoral articular cartilage

2.4.1. Ultrasonographic image acquisition

Following the timed 20-m walk protocol, the participants rested on a treatment table in a long-sit position with their knees in full extension for 30 min to unload the cartilage and minimize effects of preceding activity on the cartilage [18,19]. US images were obtained in the dominant limb, which was defined as the self-reported limb that the participant self-selected kicking a ball [18]. Participants were positioned with their back against a wall and the knee of the dominant limb positioned at 140° of flexion using a manual goniometer (Fig. 1) [18]. A tape measure was secured to the padded plinth and used to record the distance between the wall and the posterior calcaneus in order to ensure similar participant positioning at posttest [18]. A single investigator performed all femoral cartilage US imaging using a LOGIQe US system (General Electric Co., Fairfield, CT, USA) with a 12 MHz linear probe. The probe was placed transversely in line with the medial and lateral femoral condyles above the superior edge of the patella (Fig. 1) and rotated to maximize reflection of the articular cartilage surface [14,18]. A transparency grid was placed over the US screen to aid in reproducibility of the US image. Once the intercondylar notch was centered on the grid, the locations of the lateral and medial femoral condyles at the edges of the screen were recorded. This positioning was

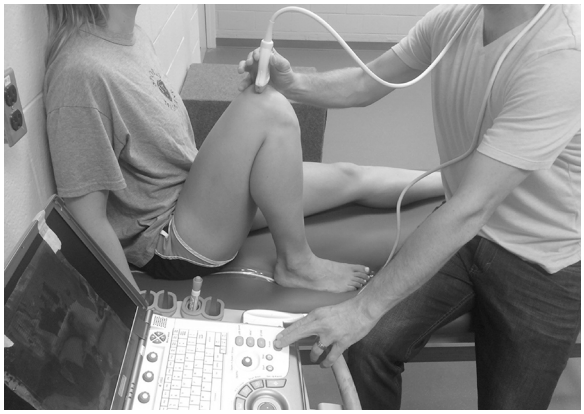

Fig. 1. Participant Setup and US Probe Positioning. Participants were seated with their test knee in 140° of flexion. The US probe was positioned transversely in line with the medial and lateral femoral condyles above the superior edge of the patella.