Gait & Posture 58 (2017) 498–503

Contents lists available at ScienceDirect

Gait & Posture

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

Full length article

The influence of divided attention on walking turns: Effects on gait control in young adults with and without a history of low back pain

Jo Armour Smith[a,b,*], James Gordon[b], Kornelia Kulig[b]

[a] Department of Physical Therapy, Harry and Diane Rinker Health Science Campus, Chapman University, 9401 Jeronimo Rd, Irvine, CA 92618, USA
[b] Division of Biokinesiology and Physical Therapy, University of Southern California, 1540 Alcazar Street, CHP-155, Los Angeles, CA 90089, USA

ARTICLE INFO

Keywords:
Walking turn
Divided attention
Low back pain
Variability

ABSTRACT

The cognitive control of gait is altered in individuals with low back pain, but it is unclear if this alteration persists between painful episodes. Locomotor perturbations such as walking turns may provide a sensitive measure of gait adaptation during divided attention in young adults. The purpose of this study was to investigate changes in gait during turns performed with divided attention, and to compare healthy young adults with asymptomatic individuals who have a history of recurrent low back pain (rLBP). Twenty-eight participants performed 90° ipsilateral walking turns at a controlled speed of 1.5 m/s. During the divided attention condition they concurrently performed a verbal 2-back task. Step length and width, trunk-pelvis and hip excursion, inter-segmental coordination and stride-to-stride variability were quantified using motion capture. Mixed-model ANOVA were used to examine the effect of divided attention and group, and interaction effects on the selected variables. Step length variability decreased significantly with divided attention in the healthy group but not in the rLBP group (post-hoc $p = 0.024$). Inter-segmental coordination variability was significantly decreased during divided attention (main effect of condition $p < 0.000$). There were small but significant reductions in hip axial and sagittal motion across groups (main effect of condition $p = 0.044$ and $p = 0.040$ respectively), and a trend toward increased frontal motion in the rLBP group only (post-hoc $p = 0.048$). These findings suggest that the ability to switch attentional resources during gait is altered in young adults with a history of rLBP, even between symptomatic episodes.

1. Introduction

Functional, goal-oriented gait requires attention to navigate environmental obstacles. Even during steady-state walking, some attentional resources are utilized for gait [1]. This is demonstrated experimentally by cognitive-motor interference when gait is performed concurrently with another attention-demanding task. Cognitive-motor interference may be increased by a reduction in the automaticity of gait, an increase in the executive control resources utilized for steady-state gait [2], or as a result of impaired attentional capacity and processing [1]. Increased cognitive-motor interference during gait is evident in older adults and individuals with multiple clinical conditions including persistent pain. This is associated with impaired functional gait performance and increased risk of falls [3,4].

The effect of cognitive-motor interference can be quantified at multiple levels of gait control. Spatiotemporal characteristics such as gait speed and step length provide information on control of overall task performance. Kinematic characteristics, such as coordination between segments (inter-segmental coordination) and individual joint excursions demonstrate how task performance is accomplished. In healthy adults, gait performance deteriorates during divided attention [5–9]. Existing evidence has demonstrated unchanged inter-segmental coordination [10], reduced [5] and unchanged lower-limb joint excursion [7] and reduced trunk excursion [11] during divided attention. However, as previous studies examined divided attention paradigms that involved additional mechanical demands, or did not control gait speed, the extent to which cognitive load alone accounts for these kinematic adaptations is unclear [5,7,11].

Adaptable locomotor behavior is facilitated by stride-to-stride variability [12]. Healthy individuals demonstrate increased step length variability [5,8], reduced step width variability [13], decreased variability in trunk-pelvis coordination [10] and decreased variability in trunk motion when attention is divided during steady-state gait [14]. Changes in variability during attention-demanding gait perturbations such as walking turns may provide further insight into cognitive-motor interference. Ipsilateral walking turns are changes in direction that occur toward the side of the stance limb. The reorientation into the new line of progression during ipsilateral turns may be accomplished within

* Corresponding author at: Department of Physical Therapy, Harry and Diane Rinker Health Science Campus, Chapman University, 9401 Jeronimo Rd, Irvine, CA 92618, USA.
E-mail addresses: josmith@chapman.edu, joarmoursmith@gmail.com (J.A. Smith).

http://dx.doi.org/10.1016/j.gaitpost.2017.09.019
Received 9 June 2017; Received in revised form 10 September 2017; Accepted 18 September 2017
0966-6362/

the stance phase of a single step (ipsilateral pivot strategy) and is achieved through rapid, axial rotation in the trunk, pelvis and hip [15,16]. As there is an immediate return to steady-state walking after the reorientation phase of the turn [15] the successful, consistent performance of the ipsilateral walking turn can be characterized by the length and width of the step immediately following the turn, and the variability of those parameters.

In people with low back pain (LBP), altered executive control of gait may result in an exaggerated response to divided attention [17]. Adults with chronic LBP demonstrate greater increases in stride length variability [17] and decreases in axial plane trunk-pelvic coordination variability [10] during divided attention compared with healthy controls. Existing studies have investigated middle-aged, symptomatic patients. In these individuals, executive function may be persistently impaired [18], or pain and fear of pain may demand additional attentional resources [1,2,19]. Many young individuals with persistent LBP have recurrent rather than chronic symptoms (rLBP) [20]. To better understand the mechanisms underlying cognitive-motor interference and LBP it is important to establish how individuals with rLBP respond to divided attention when they are asymptomatic. In particular, measures of trunk-pelvic inter-segmental coordination and joint excursion may provide valuable indices of cognitive-motor interference specific to the painful body region in this population.

The purpose of this study, therefore, was to compare the influence of divided attention on step length and width, inter-segmental coordination and joint excursion, and stride-to-stride variability during ipsilateral walking turns between asymptomatic young adults with a history of rLBP and healthy individuals. We hypothesized that in response to divided attention, all participants would demonstrate reduced step length and increased step width, increased step length/width variability, reduced trunk-pelvic and hip excursion and reduced trunk-pelvic coordination variability compared with baseline. We also hypothesized that these changes would be greater in the individuals with a history of rLBP.

2. Methods

2.1. Participants

Twenty-eight young adults participated in the study (Table 1). Participants provided written informed consent. Individuals in the rLBP group were aged between 18 and 40 years [21] with at least a one-year history of rLBP and two functionally-limiting pain episodes exceeding 24 h' duration in the preceding year [20] but were in symptom remission at the time of the data collection. Fear avoidance beliefs and impact of rLBP episodes were quantified using the Fear Avoidance Beliefs Questionnaire and the modified Oswestry Disability Index respectively [22,23]. Control participants (CTRL) had no history of low back pain and were individually matched to rLBP participants by sex, age, height, weight, and activity level.

Table 1
Participant demographics and clinical characteristics (median ± inter-quartile range).

	CTRL[a]	rLBP[a]	p
Age (years)	24.5 ± 1.75	26.5 ± 4.75	0.068
Height (m)	1.73 ± 0.05	1.73 ± 0.09	0.664
Mass (kg)	66.68 ± 14.97	67.70 ± 23.42	0.152
Time since first pain episode (years)	n/a	5.8 ± 4.2	n/a
Baseline VAS (cm)	n/a	0.12 ± 0.24	n/a
FABQ[b]	n/a	12.5 ± 6.75	n/a
ODI (%)	n/a	18.0 ± 15.0	n/a

[a] n = 14 in each group, 8 women, 6 men.
[b] physical activity sub-scale.

2.2. Instrumentation

Spatiotemporal and kinematic data were collected using an 11-camera motion capture system (200 Hz, Qualisys AB, Gothenburg, Sweden). Individual markers and marker clusters on the thorax (quantifying total trunk motion), pelvis, thighs, shanks and feet were used to define joint axes and track three-dimensional segment motion. Wireless force-sensitive resistor foot switches were attached bilaterally to the sole of participants' shoes under the heel and the first metatarsophalangeal joint (3000 Hz, TeleMyo DTS Telemetry, Noraxon USA Inc, Scottsdale, USA).

2.3. Walking turns

Participants performed multiple laps of a walking circuit that included straight walking and 90° ipsilateral walking turns (Fig. 1). Individuals with rLBP turned in the direction opposite the side of their predominant symptoms, and their matched control turned in the same direction. For both baseline (BASE) and divided attention (ATT) trials, participants performed the circuit at a controlled walking speed of 1.5 m/s ± 5%. Average speed was quantified using photoelectric triggers and trials were repeated if the participant did not maintain the correct speed. All participants spontaneously utilized an ipsilateral pivot strategy to turn.

2.4. Cognitive task

For the ATT trials, participants performed a verbal 2-back task at the same time as the walking turns. An n-back task was selected as it requires continuous attention and does not utilize visual fixation or cause direct structural interference during walking [1]. The 2-back version of the task was utilized as pilot testing demonstrated that participants found it challenging but were still able to perform the turns correctly at the controlled speed. Randomly generated strings of single digits were read to the participants at a rate of one approximately every two seconds. Participants responded "yes" when they heard a digit that was the same as one presented two digits earlier in the string. Baseline 2-back task performance was quantified during three trials in relaxed standing. During ATT trials, participants were instructed to prioritize the 2-back task over the walking turn, and were provided with feedback on the number of 2-back errors following each trial. As the duration of each trial was consistent for all participants, everyone received the same number of 2-back stimuli.

2.5. Data processing

Marker trajectories were low-pass filtered at 10 Hz. The stride cycle of each turn was determined using the voltage signals of the foot switches. Data were time-normalized within each stride cycle (Visual3D™ software, C-Motion Inc., MD, USA). Between 15 and 21 turns were analyzed for each participant for both BASE and ATT, as preliminary work indicated that a minimum of 15 trials provided stable stride-to-stride variability estimates.

2.6. Spatiotemporal variables and joint excursion

Step length and step width (post-turn step, Fig. 1) were calculated from the trajectories of the distal heel markers. For joint excursion, local coordinate systems for each segment were determined by a static calibration trial and peak-to-peak excursion of angular motion at the trunk-pelvis and hip (turn limb) was calculated across the turn stride cycle using Cardan angles [24]. The alignment of the trunk segment was normalized to the static standing trial to account for individual postural alignment [15]. Mean and standard deviation of the peak-to-peak amplitude of trunk-pelvic and hip motion was calculated for each participant and ensemble averages were calculated for the rLBP and