Gait dynamics when wearing a treadmill safety harness

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Abstract:

Nonlinear dynamics quantifies gait variability patterns, which can be useful in evaluating functional ability. A commonly used nonlinear technique is detrended fluctuation analysis (DFA). Safety support structures have previously been shown to alter DFA during gait. However, the effect of a nonweight-supporting treadmill harness on DFA during gait has yet to be determined. The purpose of this study was to determine whether a nonweight-supporting harness influenced the DFA alpha metric (DFA α) of variables typically used to examine gait function. Twenty participants (10 young adults and 10 older adults) were recruited for this study. Each participant completed one testing session on a treadmill consisting of three conditions: (1) no harness, (2) harnessed, but not attached to the support frame, and (3) harnessed and attached to the support frame. Participants walked for 15 min at the same self-selected speed for each condition. The gait variables of stride time, stride length, and step width for each condition were analyzed using DFA α to examine gait function. There were no significant interactions between age group and condition for DFA α of each variable. Additionally, there were no main effects for DFA α for age group or condition. These data indicate that a nonweight-supporting harness can be used for safety without impeding the emergence of natural gait dynamics when stride time, stride length, and step width are the primary variables of interest.

Keywords: Gait dynamics | Detrended fluctuation analysis | Treadmill harness

Article:

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1. Introduction

Gait variability has become an expansive area of research over the past two decades [1]. Specifically, the use of nonlinear dynamics to quantify gait variability patterns has led to postulates about how functional ability emerges [2] and [3]. However, to accurately assess variability patterns in gait, relatively long records of steady-state walking behavior are needed to characterize how the patterns unfold over time. Thus, a treadmill provides a convenient environment for collecting long trials so that a nonlinear dynamics framework can be utilized.

While many nonlinear analyses have been developed in recent decades [4], detrended fluctuation analysis (DFA) is a commonly used nonlinear technique to assess functional ability in clinical populations [5]. It is recommended that at least 600 consecutive strides are recorded to get an accurate measure of DFA during gait [6]. Since the required time to collect 600 strides is physically challenging for many clinical populations, support structures such as handrails are often used for safety, which has been shown to alter DFA [7]. An alternative to a handrail is a nonweight-supporting treadmill harness, which has been shown to alter ankle trajectory profiles [8]. However, these analyses were computed from a continuous time series (e.g., ankle angle), whereas DFA is typically computed from an interval time series (e.g., stride time). Thus, it is plausible that a nonweight-support harness may not influence the DFA of gait dynamics calculated from interval variables, as these variables provide a more global representation of gait control. The alpha metric (α) of DFA for gait interval variables typically fluctuates on a continuum between 0.5 and 1.0, with lower numbers indicating more random behavior and higher numbers indicating more patterned behavior [1] and [3]. DFA α for healthy adults is around 0.75 [1] and [3], so a move toward 0.5 or 1.0 when wearing a harness would represent a change in gait behavior due to the support structure. This study determined whether a nonweight-supporting harness influenced the DFA of gait interval variables that are typically used to examine gait function. It was hypothesized that no statistical differences would be observed in the DFA α of stride time, stride length, and step width between three conditions: (1) no harness, (2) harnessed, but not attached to the support frame, and (3) harnessed and attached to the support frame.

2. Method

Young adults [2M, 8F; 25.2 (1.5) years] and older adults [4M, 6F; 59.6 (10.7) years] were recruited and all participants self-reported no neurological conditions or injuries that affected their gait or balance. All study procedures were approved by the IRB at the University of North Carolina at Greensboro and all participants signed an informed consent form.

The protocol for testing was separated into three conditions, which were all completed within one testing session. The first condition was always walking without a harness on a treadmill (Simbex Active Step, Lebanon, NH). Next, participants were fitted with a harness that attached to their legs and torso (Fig. 1). In condition two, the participants wore the harness, but it was not attached to the support structure. In condition three, the harness was then connected to the support structure. The order of conditions two and three were counterbalanced between participants. Each participant self-selected their gait speed for the no harness condition and that speed was maintained for each condition. Participants walked for 15 min in each condition

(45 min total) with a 5 min break between conditions. Data were recorded from two retroreflective markers placed bilaterally on the calcanei with an eight camera Qualysis motion capture system (Gothenburg, Sweden) at 200 Hz and then exported to Visual 3D (C-Motion, Germantown, MD) to calculate the time series for stride time, stride length, and step width throughout each condition. Stride time and length were computed as the duration and anterior-posterior distance from successive right heel strikes, respectively. Step width was computed by determining the medial-lateral distance between the left and right heel marker at every right heel contact. The time series were then imported into Matlab (MathWorks, Natick, MA) to calculate DFA α for each group within each condition using box sizes of 16 to $N/9$, where N = the number of data point in the time series, as suggested by published guidelines [6]. Separate 2×3 (condition $\times$ age group) repeated measures ANOVA for each gait variable were used to compare DFA α. Statistical significance was set at $p \leq 0.05$.

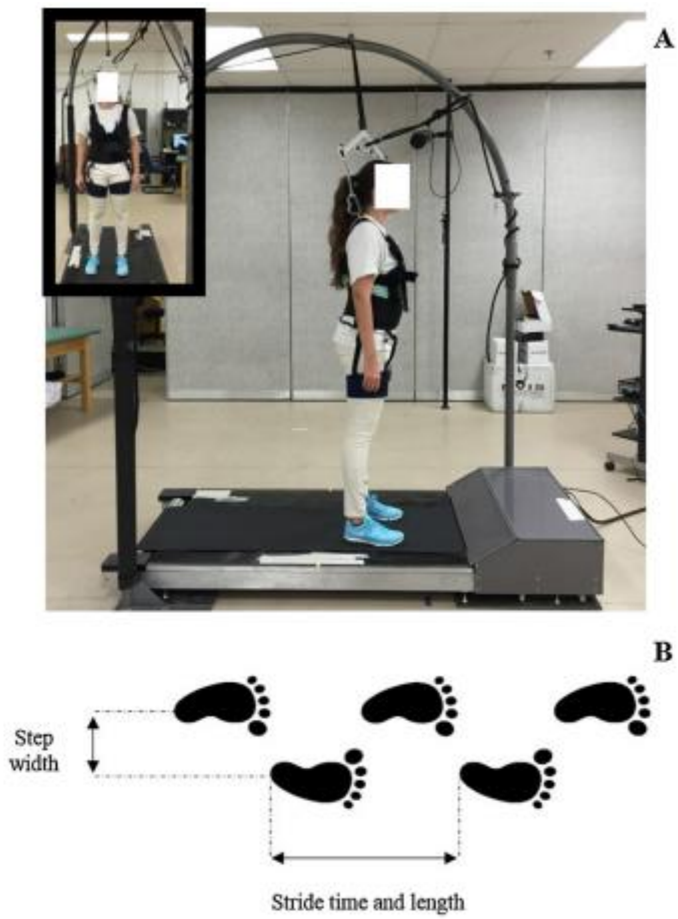

Fig. 1. Side and front view of the non-weight-supporting harness used during treadmill walking (A). The harness system was provided by the treadmill manufacturer (Simbex, Lebanon, NH). The harness attached to the participant around the torso and legs, and was tethered to a support frame. The attachment to the support frame was loose to allow for complete body movement during normal gait and would only provide support if the participant were to start falling to the ground. The bottom half of the figure shows how stride time, stride length, and step width were computed from the heel marker during the treadmill walking trails (B). Stride time and length were calculated by determining the duration and anterior-posterior distance of the marker on the right heel, respectively, from right heel contact to right heel contact. Step width was calculated by determining the medial lateral distance between the left and right heel marker at every right heel contact. This method led to an identical number of data points in each variable's time series.

3. Results

Although self-selected gait speed was higher for the older adults [0.83 (0.17) m/s] compared to the young adults [0.64 (0.09) m/s], $t(9) = -2.80$, $p = 0.021$, there was no difference in the number of strides taken between groups or conditions ($F(2,18) = 0.959$, $p = 0.402$, partial $\eta^2 = 0.10$). Young adults averaged 651.9 (47.9) strides and older adults averaged 719.3 (99.7) strides across conditions. The means and standard errors of DFA α for stride time, stride length, and step width are presented in Table 1. Statistical results are presented in Table 2.

Table 1
DFA α (unitless) for each condition. Mean values are presented with one standard deviation in parentheses.

Group	Stride time			Stride length			Step width		
	No harness	Harness not attached	Harness attached	No harness	Harness not attached	Harness attached	No harness	Harness not attached	Harness attached
Young adults	0.86 (0.06)	0.77 (0.13)	0.80 (0.15)	0.76 (0.06)	0.66 (0.15)	0.70 (0.12)	0.70 (0.13)	0.68 (0.13)	0.66 (0.08)
Older adults	0.85 (0.10)	0.84 (0.12)	0.87 (0.16)	0.69 (0.13)	0.70 (0.09)	0.75 (0.15)	0.65 (0.11)	0.68 (0.09)	0.68 (0.13)

Table 2
Statistical values for each metric and factor.

Metric	Factor	df	*F*	p-value	Partial eta squared
DFA α for stride time	condition × age group	2.36	0.890	0.442	0.044
	condition	2.36	0.898	0.416	0.048
	age group	1.18	1.470	0.241	0.075
DFA α for stride length	condition × age group	2.36	2.711	0.080	0.131
	condition	2.36	1.588	0.218	0.081
	age group	1.18	0.026	0.873	0.001
DFA α for step width	condition × age group	2.36	0.795	0.460	0.042
	condition	2.36	0.033	0.968	0.002
	age group	1.18	0.052	0.822	0.003

4. Discussion

The DFA α values in our study when not wearing the harness are consistent with previous reports [1], [3], [6], [7], [9] and [10]. Although wearing a harness does require the addition of extra material to the body, we found no evidence of altered gait dynamics when the harness was worn, regardless of whether it was attached or not attached to the support frame. This indicates that a nonweight-supporting harness can be used for safety without the potential of impeding the emergence of natural gait dynamics when interval variables are the primary interest. However, if continuous variables are of interest, such as a joint angle trajectory, previous work has shown that a nonweight-supporting harness influences gait dynamics [8]. A joint angle trajectory provides a fine-grained, local view of one link within the body's multiple segments and examining these types of continuous angles with a nonlinear dynamics framework has advanced our understanding of neuromotor control [2]. Alternatively, an interval variable, such as stride time, provides a more global measurement of gait control, as stride time is a function of the multiple joints contributing to each stride. The interval approach to studying gait control has also been beneficial in understanding neuromotor ability, especially when DFA is employed [1], [3] and [5]. Thus, our data combined with previous literature suggests that a nonweight-support harness may influence gait dynamics at the micro, but not the macro level.

An interesting second finding of this study was the lack of differences between the age groups. Previous work has shown that DFA α of stride time is reduced in older adults relative to young adults [11]. However, older adults who participated in a 6 month exercise program reduced the random variation in their gait, moving them toward more patterned behavior; similar to what is typically observed in younger adults [12]. Since the older adults in our study reported significant weekly exercise (224 min/week) and also reported having started their exercise program at least 12 months prior to our study, it is plausible that their high fitness level contributed to the faster than expected walking speed and a gait variability profile that was not different than the younger adults This is important to note, as an increase in age may not necessarily correspond to a change in gait control, especially in physically active older adults.

Conflict of interest

None.

Acknowledgments

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