TIME-TO-BOUNDARY PREDICTIONS BASED ON OTHER CENTER OF PRESSURE MEASURES IN CANCER SURVIVORS

Abigail L. Carpenter[1], Jeremy D. Smith[1], Gary D. Heise[1], Chris P. Repka[1], John H. Challis[2]

[1]Rocky Mountain Cancer Rehabilitation Institute, University of Northern Colorado, Greeley, CO
[2]The Pennsylvania State University, University Park, PA
email: abigail.carpenter@unco.edu

INTRODUCTION

Side effects associated with cancer treatments (e.g., peripheral neuropathy and vestibular dysfunction) can lead to postural instability. Balance and posture in cancer survivors has received limited attention in the literature. Previous research, on center of pressure (COP) motion, has focused on a multitude of measures to assess differences in postural steadiness based on age [1]. Using similar COP assessments, postural steadiness was investigated in cancer survivors where surface and vision conditions were altered [2,3]. It was observed that the following time-domain based measures were influenced by surface and vision conditions: root-mean-square (RMS), path lengths, mean velocity, 95% confidence ellipse area [2]. The following frequency-domain measures were also found to be influenced by surface and vision conditions: mean frequency, fractal dimension of the confidence ellipse (FractCE), and total power [3].

Recently, time-to-boundary (TTB) has been utilized to assess postural steadiness. TTB predicts the time it would take the COP to reach the limits of the base of support [4]. Lower TTB measures are associated with greater postural unsteadiness; that is, less time is available to recover from a balance perturbation [5]. TTB has been evaluated in older adults during quiet standing, and the results indicate that TTB is reduced with aging [4]. In addition, TTB has been examined in a young, healthy population during single leg standing to examine how a reduced base of support affects TTB measures [6]. Hertel et al. [6] also investigated relationships between TTB and traditional COP measures; they suggested that TTB provides unique insight into postural steadiness for single leg standing. TTB has not been applied specifically to cancer survivors as a means of assessing postural steadiness.

TTB is a more involved calculation than traditional COP-based measures, but it can be useful when assessing the risk of falling. It is unclear whether TTB provides information beyond the traditional COP-based measures of posture and balance in cancer survivors. Therefore, the purpose of this study was to determine whether TTB could be predicted by traditional COP measures, which were previously found to be sensitive to changes in vision and surface conditions [2,3].

METHODS

Quiet standing was measured in cancer survivors (n=11; mass = 75.6 ± 22.1 kg; height = 1.60 ± 0.05 m; age = 56 ± 14 years) during four different conditions. Participants stood on a rigid surface with eyes open, a rigid surface with eyes closed, a compliant surface with eyes open, and a compliant surface with eyes closed. Force data were collected for 30 s at 1000 Hz. COP data were resampled at 50 Hz for TTB assessments. The TTB algorithm was based on previous literature [4]. The algorithm produced a time series of TTB with multiple minima. The minimum value from each of these local minima was selected as our dependent measure of TTB. A lower TTB is indicative of postural unsteadiness, and these minima illustrate the least amount of time individuals have to recover from a balance disturbance. Because our focus was not on the differences between conditions, but rather on the ability of traditional COP measures to predict TTB, we chose to collapse data across conditions. This decision impacted our statistical analysis, increasing our sample size from 11 to 44, which resulted in a subject to variable ratio of 4.4:1.

Stepwise linear regression was used to determine whether TTB could be predicted from traditional

COP measures which previously showed sensitivity to changes in surface and vision conditions [2,3]. Ten traditional COP measures were used to predict the TTB absolute minima: mean medial/lateral (ML) and anterior/posterior (AP) frequency, ML and AP COP path lengths, fractal dimension of the confidence ellipse, RMS of the ML and AP COP, mean velocity of the ML and AP COP, and the 95% confidence ellipse area.

RESULTS AND DISCUSSION

Four significant regression models were identified based on the independent variables (Table 1). The first model chosen was based on the mean velocity of the ML COP, indicating that this variable had the highest correlation with TTB. In the second model, RMS of the ML COP was added to the prediction, which increased the explained variance by 9%. In the third model, FractCE was added to the model, which further increased the explained variance by another 5%. A fourth model was also predicted that explained the same amount of variance as model 3 (47%), but eliminated the mean velocity of the ML COP from the prediction. Thus, the mean velocity of ML COP and the RMS of ML COP explain the same amount of variance in TTB when FractCE is also considered. Model 4 was considered the best model for predicting TTB. However, no model explained more that 47% of the variance in TTB, suggesting traditional COP measures are not good predictors of TTB. TTB was independent of the frequency-based COP measures, which was expected, given that TTB is derived from time-domain measures of the COP, specifically velocity and the position of the COP.

Our results are consistent with previous suggestions in the literature that TTB evaluates different aspects of postural steadiness than traditional COP measures [6]. Hertel et al. [6] observed that correlations between TTB measures and traditional COP measures (mean velocities, COP range, and COP standard deviation) ranged from 0.03-0.90 (i.e., $r^2 \approx 0.0009 - 0.81$). Interestingly, the highest correlations were reported between ML COP velocity and TTB (range ≈ 0.47-0.90). This is consistent with our predictions in that ML COP velocity was the first variable to enter the stepwise regression model even though the best model ultimately did not include this measure. Instead, RMS of the ML COP was used to replace ML velocity. As with our previous results [2,3], it appears that ML COP measures are important indicators of postural steadiness. Therefore, ML COP measures should be included when assessing postural steadiness in cancer survivors.

Table 1. Regression models for predicting TTB based on traditional COP measures.

Model	**Predictors**	R^2	***F***	***p***
1	ML Mean Velocity	0.33	20.9	< .001
2	ML Mean Velocity, ML RMS	0.42	14.6	< .001
3	ML Mean Velocity, ML RMS, FractCE	0.47	11.9	< .001
4	ML RMS, FractCE	0.47	18.3	< .001

Note: Regression equation for each model:
TTB_1 = -0.037*ML Mean Velocity+0.676
TTB_2 = -0.025*ML Mean Velocity-0.043*ML RMS + 0.720
TTB_3 = -0.0001* ML Mean Velocity -0.085*ML RMS-1.008*FractCE +2.170
TTB_4 = -0.85*ML RMS-0.999*FractCE+2.158

CONCLUSIONS

Although TTB was predicted by ML RMS and FractCE, traditional COP based measures did not fully explain variability in TTB. This suggests that TTB provides further insight into mechanisms underlying posture and balance in cancer survivors.

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