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ORIGINAL ARTICLE

Standing Data Disproves Biomechanical Mechanism for Balance-Based Torso-Weighting

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Abstract

Objective: To test a proposed mechanism for the effect of balance-based torso-weighting (BBTW) in people with multiple sclerosis (MS) and healthy controls. The mechanism to be tested is that application of light weights to the trunk may result in a biomechanical shift of postural sway in the direction of weighting, mechanically facilitating maintenance of the center of mass over the base of support.

Design: Nonrandomized controlled trial.

Setting: Motion analysis laboratory.

Participants: Participants with MS (n=20; average Expanded Disability Status Scale score, 4.1) and controls matched for sex, age, height, and weight (n=18).

Intervention: Light weights strategically placed according to the BBTW protocol were applied to all participants after at least 3 walking trials and 10 seconds of quiet standing with feet together and eyes open and then eyes closed. Measures were repeated after weighting.

Main Outcome Measure: Forceplate center of pressure (COP) changes >1 standard error of measurement.

Results: With BBTW, people with MS had larger maximum changes in COP than healthy controls in the left-right direction but not in the anterior-posterior direction. COP changes >1 standard error of measurement occurred in the same direction of weighting 20% of the time (95% confidence interval, 5−34), ranging from 10% to 28% across conditions and directions of postural sway. Direction of greatest weight placement did not match the direction of change in the average COP in most participants with MS or the healthy controls in eyes open or eyes closed conditions ($P<.001$).

Conclusions: If BBTW worked via a biomechanical shift of the center of mass, COP changes should match the direction of greatest weighting with BBTW. Our data allowed us to reject this hypothesis. Future research may explore alternative mechanisms of action underlying this intervention.

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Multiple sclerosis (MS) is a neurodegenerative disease affecting approximately 2.5 million people worldwide. Each year, 10,000 new cases are identified in the United States, usually in people between the ages of 20 and 50, making MS the most common progressive neurologic disease in young adults.[1] MS results in demyelination and destruction of central nervous system axons, thus slowing or halting the conduction of neural impulses, frequently affecting postural control during upright movement. Between 87% and 94% of those with MS report impaired balance and mobility.[2,3] Additionally, 52%[4] to 54%[5] of younger and middle-aged people with MS report having fallen recently. Many report multiple falls,[6] and 50% of those age >55 years report falls resulting in injury.[2] Therefore, improving balance and mobility is an integral component of rehabilitation for people with MS.

One rehabilitative intervention that has affected measures associated with fall reduction is balance-based torso-weighting

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(BBTW).[7] Unlike previous reports of the use of weights in rehabilitation in which larger fixed amounts of weight (3.6%−10% body weight) are placed at a standardized location at the waist or shoulders,[8,9] BBTW begins with assessment of an individual's unassisted balance during quiet and perturbed standing and continues with trials of resisted rotation of the trunk at the shoulders and pelvis. Light weights are then strategically placed onto a garment worn on the torso until the person can resist perturbations with greater ease and produce more symmetrical responses during resisted rotation. BBTW has resulted in immediate improvement in functional measures in people with MS,[7,10,11] with the potential for reducing their fall risk. However, the mechanism for the effectiveness of BBTW is unknown, thus restricting hypothesis-driven application to appropriate populations.

Multiple mechanisms have been proposed to account for the immediate improvements seen with a rehabilitative weighting protocol. Potential mechanisms include joint compression, increased inertia, increased afferent input about body segments, and improved conscious awareness.[9,12,13] Many of these mechanisms imply that added weights must be substantial in order to improve mobility by compressing joints, changing the moment of inertia, or increasing awareness of a body segment. The immediate functional improvements with the modest amount of weight (<1kg) used in BBTW[7] indicate that effectiveness for this intervention does not require substantial weight. Because the BBTW protocol results in strategic, rather than symmetrical, weight placement, an alternative mechanism might be that weights result in a biomechanical shift in postural sway, observable as a change in the location of the center of pressure (COP) on a forceplate in the direction of the most weight placed. For example, adding weight to the right side of the upper body might shift the COP to the right. The biomechanical shift may mechanically facilitate maintenance of the center of mass over the base of support, making balance and walking easier when weighted. Clinical observation, however, has suggested that changes in postural sway patterns with BBTW may not match the direction of weight placement. No previous studies, to our knowledge, have negated a strictly biomechanical mechanism for functional changes with BBTW nor established an association between weight placement and COP shifts.

The purpose of this study was to investigate biomechanical shift as the mechanism for BBTW. We recorded the COP during static standing with eyes open (EO) and eyes closed (EC) in people with MS and matched healthy controls in unweighted and weighted conditions, placing weights using the BBTW protocol. If a biomechanical shift occurred, changes in the COP would be expected to match the placement of weights on the body, with anterior placement of weights resulting in a shift of COP anteriorly, for example. A nonmatch would be no shift or a shift in the opposite direction. To test this, we proposed a null hypothesis of no difference between the number of matches and nonmatches; equal numbers of matches and nonmatches would indicate a random response to the direction of weight placement. If the evidence was sufficient to reject the null hypothesis, examination of the actual proportions of matches with 95% confidence intervals would indicate the direction of our findings. If a biomechanical shift occurred, the direction of change in COP should match the direction of weight placement >50% of the time. This investigation was part of a larger study that involved motion analysis of gait in unweighted and weighted conditions.[14]

List of abbreviations:

BBTW	**balance-based torso-weighting**
COP	**center of pressure**
EC	**eyes closed**
EDSS	**Expanded Disability Status Scale**
EO	**eyes open**
MS	**multiple sclerosis**

Methods

Participants with MS were recruited through the Northern California Chapter of the National Multiple Sclerosis Society and local neurologists' offices. Eligibility criteria included a self-reported diagnosis of MS, the ability to communicate in English, ≥18 years of age, ability to ambulate at least 7.62m (with or without an assistive device), reported balance or mobility difficulties, and sufficient endurance for up to 3 hours of testing with rest breaks. Individuals were excluded from this study if they reported an exacerbation of MS within the last 2 months, had a diagnosis of a concurrent neurologic disorder (head injury, stroke, Parkinson's disease, etc), or reported pain that could be exacerbated by external perturbations during standing or multiple trials of walking.

Healthy controls were matched to the participants with MS by sex, age, height, and weight. Individuals were recruited through personal contacts and online postings on www.craigslist.org. Eligibility for control participants included the ability to communicate in English; characteristics that matched a participant with MS within a predefined range of age, height, and weight; and the absence of any known diagnoses or current pain that would affect balance or gait. All participants in this study gave informed consent. This study met the requirements for ethical research according to the Institutional Review Board of San Francisco State University.

Participants completed a medical questionnaire about symptoms, walking ability, and fall history. Responses to the medical questionnaire were used to determine approximate levels of disability, represented as equivalence scores on the Expanded Disability Status Scale (EDSS) between 0 (normative neurologic function) and 10 (death because of MS). Clinical measures were recorded for each participant, including height, weight, number of falls, and self-reported visual or sensory dysfunction. Participants donned an unweighted BBTW garment[a] adjusted to fit their trunk height, waist, and chest dimensions. Participants with MS performed 3 fast-speed walking trials prior to static standing on the force platform and were given rest breaks as needed. Healthy controls performed 3 fast-speed walking trials and then performed additional walking trials to match the gait velocity of the MS participant with whom they were paired. The walking trials were part of a larger study investigating the effects of BBTW on gait temporal and spatial parameters.

COP data were collected in the anterior-posterior and left-right directions without weighting while participants stood still with their feet together on a Kistler forceplate[b] (sampling at 600Hz). Participants were instructed to stand as still as possible for a 10-second trial with their EO and then a trial with their EC. A researcher stood near the participants during the testing and weighting protocols to monitor for undesired foot movement and to guard in case of an unrecoverable loss of balance.

Balance assessment was performed using the BBTW protocol.[7,10] Assessment of balance included observation of