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Poster Abstracts from the Eighth International Symposium on Gait and Balance in Multiple Sclerosis: Exercise – Symptom Management to Disease Modification

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(1) Inter-Rater Reliability of Assessing Balance Loss After Perturbation in the Balance-Based Torso-Weighting Method of Improving Gait and Balance

Allen DD,[1] Magdalin C,[1] Schultz A,[1] Scott K,[1] Jang C,[1] Hughes R,[1] Vivero L,[1] Widener GL[2]

[1]Graduate Program in Physical Therapy, University of California San Francisco/San Francisco State University, San Francisco, CA, USA; [2]Department of Physical Therapy, Samuel Merritt University, Oakland, CA, USA

Background and Purpose: In multiple sclerosis (MS), Balance-Based Torso-Weighting (BBTW) has resulted in balance and gait improvements when light weights are strategically placed on the trunk according to the direction of balance loss with perturbations. Perturbations are applied manually as nudges and rotational forces in six prescribed directions at shoulders and pelvis. No reliability studies have examined the inter-rater reliability of assessing direction of greatest balance loss, the determinant for weight placement in BBTW. Examine inter-rater reliability of the BBTW method of assessing direction of balance loss with manual perturbations. **Methods:** Four physical therapists with various amounts of BBTW training and experience assessed direction of balance loss in 10 healthy volunteers. Subjects were assessed by at least two therapists. Therapists assessed at least six subjects. Each subject had 30 minutes between sessions; all assessment sessions were videotaped and completed within a 4-hour period. Six trained reviewers viewed videos and scored balance loss following perturbations. At least four reviewers examined videos for each therapist. Score of balance loss was rated using a rubric where 0 indicated normal, quick balance response; 1-3 indicated progressively greater body movement and slower recovery of upright orientation; 4 indicated that the subject would have fallen without clinician assist following a perturbation. Intra-class Correlation Coefficients (ICC) and measures of agreement were assessed across reviewers for each therapist. **Results:** ICCs ranged from 0.57 to 0.78 within the four therapists. Agreement within one point for each perturbation scored on the rubric across five to six reviewers for each therapist ranged from 0.80 to 0.93. The highest ICCs and agreement values were aligned with the most experienced therapist. **Discussion:** Assessing direction of balance loss has moderate

to good inter-rater reliability and good to excellent agreement. Clinicians and reviewers can be trained to provide reliable results for BBTW.

(2) Steadiness of Submaximal Isometric Contractions of the Ankle Dorsiflexors and Elbow Flexors in People with Multiple Sclerosis

Bunyan SL, DePauw EM, Flanagan AM, Ng AV

Exercise Science Program, Physical Therapy Department, Marquette University, Milwaukee, WI, USA

Background and Purpose: Young and older adults both exhibit greater isometric force variability at lower forces and there is a correlation between steadiness in muscles of the upper and lower extremities. Force steadiness in people with multiple sclerosis (PWMS) has only been examined in the plantar flexors at 20% of the maximum voluntary contraction (MVC) force and PWMS were shown to be less steady than controls. The aims of this study were to examine force steadiness during non-fatiguing, isometric contractions across a range of forces in PWMS and determine if force fluctuation correlates at matched force levels in upper and lower extremities. **Methods:** Force steadiness was measured in elbow flexors and ankle dorsiflexors. After determining MVCs, submaximal target forces were calculated for 2.5%, 5%, 15%, 30% and 45% MVC. Two 15-second steadiness trials were performed at each target force. Coefficients of variation (CV) were calculated over 5-second intervals. Data were analyzed using ANOVA, t-tests, and Pearson product-moment correlations. **Results:** Fifteen PWMS (49.7+9.48 years; PDDS 0.93+1.33; 10 female) with relapsing-remitting MS participated. Force fluctuation (CV) was greatest at low forces for both the elbow and ankle [Elbow: 2.5%=5.68+1.98, 5%=4.10+2.00, 15%=2.61+1.71, 30%=2.72+1.22, 45%=3.09+1.59; Ankle: 2.5%=7.88+4.30, 5%=4.84+2.39, 15%=1.92+0.91, 30%=1.81+0.44, 45%=1.95+0.99]. Values for ankle and elbow CV were significantly different at 30% and 45% MVC ($P < .05$), but not different at lower forces ($P > .05$). Correlations between CV of upper and lower extremity muscles were not significant ($P > .05$) at any matched force level. **Discussion:** Consistent with other findings in healthy adults, PWMS are less steady when performing isometric contractions at low forces in both the upper and lower extremities. Contrary to other findings, steadiness of upper and lower extremity muscle groups did not correlate. This finding suggests that PWMS may use different control strategies for upper and lower limbs.

(3) The CoDuSe Balance Exercise Reduces Falls and Improves Balance in People with Multiple Sclerosis

Carling A,[1,2] Forsberg A,[2] Nilsagård Y[3]

[1]Faculty of Medicine and Health, Örebro University, Örebro Sweden; [2]Department of Physiotherapy, Örebro University Hospital, Örebro, Sweden; [3]Health Care Management, Region Örebro County, Örebro, Sweden

Background and Purpose: Imbalance and falls risk are common in people with multiple sclerosis (PwMS). The CoDuSe balance exercise was developed to target core stability, dual tasking and sensory strategies. Sixty-minute group sessions are provided twice weekly over 7 weeks. Quantitative and qualitative study designs have been used to evaluate the effects in two separate samples of PwMS. A waiting list design was used for the RCTs where participants were randomized to either early or late intervention start. Falls were self-reported daily using fall diaries. A faller was defined as a person reporting ≥1 fall during a 7-week period. Balance was evaluated using Bergs Balance Scale (BBS) as primary outcome; pre- and post-intervention and at 7 weeks follow-up. Interviews were conducted after follow-up. The purpose was to describe the effects of the CoDuSe exercise on balance, falls and impact on everyday activities by combining data from these studies. **Methods:** Data-sets were created from the RCTs (n = 121). Falls data were available from the two subgroups starting intervention late. 27 participants in one of the RCTs were asked and agreed to be interviewed[4]. All participants had limited but remained walking ability and impaired balance function. **Results:** There were significant differences in balance between groups; BBS (P = .006) in favor for the intervention group, mean improvement 2.17 (confidence interval 0.64; 3.73). Thirty-three participants were classified as fallers before intervention compared to 16 after. A statistically significant decrease ($P \leq .001$) in numbers of falls was found between before intervention (256) and at follow-up (80) ($P \leq .001$). Participants described improved core stability and ability to perform activities in everyday life more easily thus increasing participation. **Discussion:** Seven weeks of twice weekly CoDuSe balance exercise program improves balance, increases participation and reduces number of falls and fallers in PwMS with limited walking ability and imbalance.

(4) Motor Fatigability Impacts Lower Extremity Kinematics During Prolonged Walking in People with Multiple Sclerosis

Cohen ET,[1] Muth S,[2] Dekerlegand RL,[2] Ferraro R[1]

[1]Department of Rehabilitation and Movement Sciences, Rutgers, The State University of New Jersey, Blackwood, NJ, USA; [2]Doctor of Physical Therapy Program, Thomas Jefferson University, Philadelphia, PA, USA

Background and Purpose: Fatigability, a decline in physical performance with repetition, is common in people with multiple sclerosis (pwMS). The purpose of this study was to quantify changes in lower extremity kinematics (LEK) during prolonged walking in a sample of pwMS and to examine the relationship between changes in LEK and self-report measures of disease severity, walking and fatigue. **Methods:** Thirteen people with a confirmed MS diagnosis completed this study (11 women; mean age = 57

(± 4.4), median Disease Steps (DS) and Patient Determined Disease Steps (PDDS) were 3 (IQR = 1 and 3, respectively). Participants completed the Modified Fatigue Impact Scale (MFIS) and 12-item Multiple Sclerosis Walking Scale (MSWS-12). Participants walked continuously for 12 minutes along a 58-foot-long, obround track. LEK was measured during the 1st and last minutes of the walk with 3-D motion tracking. Perceived fatigue was rated before and after the walk using a visual analogue scale (VAS-F) with the difference calculated as ΔVAS-F. Differences in excursion magnitudes at minutes 1 and 12 at left and right ankle, knee and hip flexion, and hip abduction, and all joints combined, were analyzed with paired samples t-tests were. Relationships between LEK differences and self-report measures were examined with Spearman's correlations. **Results:** The magnitude of combined joint excursion changed over time as did total excursion for each joint ($P < .05$). LEK changes did not correlate with any self-report measure. **Discussion:** This study confirms that LEK in pwMS change during prolonged walking. Like the disease itself, the differences varied widely between participants. This study also confirms evidence that self-report measures do not correlate well with functional performance. Objective, multifactorial measures must be developed to better describe the impact of fatigability on gait and walking.

(5) Stabilization of Center of Mass Is Preserved in Individuals with Multiple Sclerosis

Gera G,[1] Reimann H,[3] Horak FB[2]

[1]Rehabilitation Sciences, University of Kentucky, Lexington, KY, USA; [2]Neurology, Oregon Health and Science University, Portland, OR, USA; [3]University of Delaware, Newark, DE, USA

Background and Purpose: Quiet stance requires complex integration of somatosensory, vision, and vestibular information for postural control. Healthy individuals depend primarily upon somatosensory information to control postural sway when standing on a stable surface with vision available. However, in multiple sclerosis (MS) subjects, somatosensation, especially in the feet, is impaired due to demyelination and axonal degeneration of spinal and supraspinal axons in sensory pathways. We investigated the coordination among body segments with respect to the stabilization of the CoM during a quiet stance task and the effects of vision on CoM stability in people with MS and healthy individuals. We hypothesized that individuals with MS will have impaired coordination leading to reduced stability of the CoM, more so for the eyes closed condition than the eyes open condition. **Methods:** Subjects were asked to stand quietly with either eyes open (EO) or closed (EC). We analyzed the structure of postural sway variance in joint space using the uncontrolled manifold (UCM) approach. Kinematic data for 17 MS subjects (EDSS: 2-4) and 10 control subjects were analyzed. **Results:** Overall, joint configuration variance was higher for the MS group compared to the control group ($F_{(1,25)} = 5.02$, $P < .05$). However, the component of joint configuration variance that affects the CoM position was found to be substantially lower than joint

configuration variability leaving the CoM position stable ($F_{(1,25)} = 12.46$, $P < .01$) irrespective of whether eyes were open or closed for both the MS and control groups. **Discussion:** Our findings indicate that joint configuration is more variable for mildly impaired subjects with MS, as compared to the healthy individuals. However, the structure of variance is not different from healthy individuals, indicating that the active coordination between different body segments remains intact.

(6) Temporal Variability in Multiple Sclerosis Gait and Balance Measures: Partial Results of an Ongoing Study

Karpatkin H, Hui R, Long M, Petti A, Sonnenberg H

Doctorate in Physical Therapy Program, Hunter College, New York, NY, USA

Background and Purpose: Accurate measurement of gait and balance dysfunction is an integral part of multiple sclerosis (MS) rehabilitation. However, MS is well known to be a disease of considerable variability, suggesting that a single measurement may not always accurately represent the patent's status. The purpose of this study is to examine if variability exists in common MS mobility measures if measured multiple times over a 12-week period. We hypothesize that there will be considerable variation in these measures over this period. If our hypothesis is correct, it will suggest that a single measure may not be an accurate representation of pwMS's mobility. **Methods:** Subjects with a definitive diagnosis of MS were measured using the MiniBESTest (MBT), the 6-Minute Walk Test (6MWT), the 25-foot walk test (25FWT), and the Stair Climbing Power Test (SCPT). Testing will be performed once daily for 3 consecutive days, once weekly for 3 consecutive weeks, and once monthly for 3 consecutive months. **Results:** To date, four subjects (2 female, 2 male, EDSS 4.4) have completed the study. Preliminary descriptive statistics measuring mean score ranges for all subjects are as follows: Mean MBT score range: 4 points; mean 6MWT range: 127.7 feet; mean SCPT score range: 4.95 seconds; 25FWT range: 4.6 seconds. **Discussion:** Depending on the day, scores in MS mobility measures presented with considerable variability. This variability is equal to or greater than the Minimal Detectable Change for the 6MWT, MBT, and the 25FWT. Clinicians should take this into account when evaluating mobility deficits in these patients, as it suggests that a single measurement may not accurately represent the patient's true abilities and potentially result in inappropriate intervention strategies. Data collection for this study will continue through December of 2018.

(7) Effect of an Ankle Flexibility and Strength Program on Gait in Persons with Multiple Sclerosis: Partial Results of an Ongoing Study

Karpatkin H, Babyar S, Dunfey M, Kleiner R, Petersen A, Saliente R

Doctorate in Physical Therapy Program, Hunter College, New York, NY, USA

Background and Purpose: Evidence indicates that impaired ankle push-off may be a cause of gait dysfunction in persons with Multiple Sclerosis (pwMS), suggesting that interventions which address push-off may improve gait. The purpose of this ongoing study is to determine the effect of a home exercise program (HEP) targeting impairments related to ankle push-off on gait performance in pwMS. **Methods**: Subjects are being recruited from local MS practices. Push-off impairment is determined by diminished ankle plantarflexion and or dorsiflexion strength or range of motion (ROM) as measured by hand held dynamometry (HHD) and goniometry. Primary gait outcome measures are the 6-minute walk (6MWT), Dynamic Gait Index (DGI) and kinematic data as measured by the Zeno™ walkway using Protokinetics Movement Analysis Software during the 1st and 6th minutes of the 6MWT. A 6-week individualized HEP was based on the HHD and ROM measurements. Patients received a weekly phone call to monitor HEP compliance. After 6 weeks, all outcome measures we repeated. Nonparametric Friedman Tests compared minute 1 values for the gait parameters across weeks. **Results:** To date, 5 subjects (Mean EDSS 4.7, ± 1.2) have completed the training. Mean 6MWT distances have improved from 1011.4' to 1069.8', and mean DGI scores have improved from 14.2 to 17. Based on an average of 17 steps per person, mean stride velocity in the 1st minute of the 6MWT improved from 41.6 cm/s to 45.02 cm/s (P = .069). Percent time in stance increased (P = .014). Gait velocity increased from 85.1 cm/s to 93.9 cm/s. Although improved, gait velocity and cadence did not show significant differences across weeks. Intersubject variability was high. **Discussion**: Preliminary data shows improved scores in various MS gait and kinematic measures following an HEP targeting limitations related to diminished ankle push-off. Data collection will continue through the December of 2019.

(8) Review of Yoga/Mindfulness Literature on Persons with Multiple Sclerosis

Kushner S

Slippery Rock University of Pennsylvania, Butler County, PA, USA

Background and Purpose: Persons with multiple sclerosis (MS) have numerous physical challenges associated with the disease that prevent normal activity and exercise. Being a progressive neurological disease, activities must be found that can accommodate the changing abilities of the patient. Those involved with the patient must find interventions that allow for changing functional status as time goes on. Yoga means "to join." It is a practice of movement that intends to join mind and body, including mindfulness. Mindfulness is a practice of living in the moment, practicing gratitude, slowing down the mind. There exist a number of types of yoga, each with a different intent. Numerous studies have shown that yoga can have positive effects on both the body and the mind. Persons with MS struggle not only with physical limitations, but also with depression and anxiety. As with any progressive neurological disease, the unknown future and the realization of a downward course can be overwhelming and

difficult to surmount on a daily basis. As yoga and mindfulness become more popular, healthcare practitioners are incorporating these practices more and more into patients' wellness routines with very positive results. Some studies report increases in a variety of physical domains such as balance, strength and flexibility, while other show improvements in quality-of-life measures and self-efficacy. This poster will attempt to summarize past and current literature related to MS and encourage in increase of clinical research in this area of treatment for patients. **Methods:** Literature review from numerous disciplines. **Results:** Comprehensive information for healthcare professionals. **Discussion:** Review of current findings with the intent of promoting further clinical research in this area.

(9) Strengthening of Ankle, Hip, and Trunk to Improve Gait in People with Multiple Sclerosis: A Feasibility Study

Mañago MM,[1,2] Hebert JR,[1,2] Schenkman M[1]

[1]Physical Therapy Program, Department of Physical Medicine and Rehabilitation, and [2]Department of Neurology, School of Medicine, University of Colorado Denver, Aurora, CO, USA

Background and Purpose: In people with multiple sclerosis (MS) strength intervention trials consistently improve strength, but not gait. Our recent work has concluded that this may be because current strengthening studies focus on knee extension, while ankle plantarflexion, hip abduction, and trunk muscles are the strongest predictors of gait performance in people with MS. The purpose of the current study was to investigate the feasibility of improving strength and gait outcomes following strength training for ankle plantarflexion, hip abduction, and trunk flexion in people with MS. **Methods:** Intervention consisted of an 8-week strength training program for ankle plantarflexion, hip abduction, and trunk muscles using a repeated-measures design with two baseline assessments and a single post-intervention assessment. The Outcomes included adherence and satisfaction, strength in lower extremity and trunk muscles, gait speed (Timed 25-Foot Walk [T25FW]), gait endurance (6-Minute Walk Test [6MWT]), and self-reported gait-related participation (Multiple Sclerosis Walking Scale-12 [MSWS-12]). **Results:** Ten participants (nine females), Expanded Disability Status Scale score 3.5 to 5.5, completed the intervention. Median level of satisfaction with the intervention was "very satisfied," and all participants were at least "satisfied." Adherence was 87% and 75% for supervised and home sessions, respectively. Strength improved in primary muscle targets between 23.1 and 47.6% ($P < 0.001$ to 0.039). T25FW (–13.4%, $P < .001$), 6MWT (41.56 meters, $P = .019$), and MSWS-12 (–10.5, $P = .007$) also improved significantly. **Discussion:** Strength training of ankle plantarflexion, hip abduction, and trunk muscles in people with MS was feasible and associated with meaningful improvements in gait outcomes. As these muscles are not commonly targeted for people with MS, a future randomized control trial targeting these muscles is warranted.

Meanwhile, rehabilitation clinicians might consider these muscles during evaluation and treatment of patients with MS who have a goal of improving gait.

(10) Vibration Sensitivity and Foot-Tapping Distinguish Non-Progressive from Progressive Multiple Sclerosis in the Absence of Overt Gait Differences

Miehm JD,[1] Sato S,[1,2] Lim J,[1,4] Rajala C,[1] Kelly M,[1] Averill L,[1] Ionete C,[5] Buonaccorsi J,[3] Van Emmerik REA,[1] Kent JA[1]

[1]Department of Kinesiology, [2]Department of Neuroscience and Behavior, [3]Department of Math and Statistics, University of Massachusetts, Amherst, MA, USA; [4]Department of Counseling, Health and Kinesiology, Texas A&M University, San Antonio, TX, USA; [5] Department of Neurology, University of Massachusetts Memorial Medical Center, Worchester, MA, USA

Background and Purpose: At diagnosis, ~85% of people with multiple sclerosis (MS) are classified as non-progressive (NP_{MS}). Within 25 years, ~90% of these individuals will transition to progressive MS (P_{MS}). There are no established criteria to identify a transition from NP_{MS} to P_{MS}, and so detection is retrospective and delayed. Our goal was to determine whether measures of sensorimotor or mobility function can distinguish NP_{MS} from P_{MS}, as these may constitute promising markers of transition to P_{MS}. **Methods:** 31 NP_{MS} (28 women, 52.6 $\pm$ 9.9 years), and 32 P_{MS} (21 women, 59.5 $\pm$ 8.7 years) were evaluated for vibration perception threshold (VPT; Biothesiometer) on the plantar surface of each foot. Joint position sense was measured with an ankle manipulandum using a position-matching task. Central motor drive was evaluated during a 10-s rapid foot tap test (FTT) using inertial sensors. Mobility was evaluated during the timed 25-foot-walk (T25FW) at preferred speed while wearing inertial sensors to measure double support time, gait speed, step duration, and stride length. **Results:** Only VPT and FTT distinguished NP_{MS} from P_{MS} (table 1). **Discussion:** Relative to NP_{MS}, P_{MS} had impaired sensory (VPT) and motor (FTT) function, but no difference in mobility function, suggesting that VPT and FTT could prove useful for early detection of a transition from NP_{MS} to P_{MS}, and thus facilitate treatment plans for people with P_{MS}.

(11) Automated Fall Detection in People with Multiple Sclerosis Using a Context-Aware Movement Tracking System

Mosquera-Lopez C,[1] Wan E,[2] Folsom J,[1] Hildebrand A,[3] Leitschuh J,[1] Oganessian S,[1] Cameron MH,[1,3] Jacobs PG[1]

[1]Oregon Health & Science University, Portland, OR, USA; [2]Portland State University, Portland, OR, USA; [3]VA Portland Health Care System, Portland, OR, USA

Background and Purpose: People with multiple sclerosis (MS) fall frequently, but accurately detecting falls in a timely manner is challenging. Prospective daily self-report fall calendars are the current gold standard but these are burdensome, frequently inaccurate, and do not provide contextual information about the fall. We therefore developed a wearable, context-aware movement tracking system with a machine learning algorithm to automatically detect and localize falls in people with MS. In this presentation, we show results on the fall detection accuracy. **Methods:** Twenty-six ambulatory subjects with MS (EDSS ≤ 6.0) reporting at least two falls or near falls in the previous 2 months were monitored with the Motiosens smart system for 8 weeks**.** Subjects wore the system's wireless tag throughout the day and self-reported falls on a paper calendar and by pressing a button on the tag. The tag's embedded 3-axial accelerometer's inertial data were processed with semi-supervised machine learning. A recurrent neural network auto-encoder was trained on the magnitude of the accelerometer vector $\|A\| = \sqrt{a_x^2 + a_y^2 + a_z^2}$ using segments of normal activities and abnormal events were detected based on a threshold on the reconstruction error. To reduce false alarms, a decision tree model with additional descriptors was used and then leave-one-out cross-validation optimized the area under the curve (AUC) for true vs. false positive rate. **Results:** The average AUC in subjects with at least one fall was 0.9. Maximizing sensitivity to close to 100% was associated with an average of 2.3 false positive alarms per day. Higher false positive rates were obtained when leaving out subjects with many falls. **Discussion:** With this fall detection system we can detect falls with high sensitivity and specificity. However, when optimized for high sensitivity to capture the majority of falls events there are many false alarms. We are currently developing approaches to further optimize accuracy by integrating context information obtained from the Motiosens system.

(12) Moving Stronger at the YMCA: Preliminary Results of a 12-Week Group Exercise Program for People with Multiple Sclerosis

Garcia-Tarodo S,[1] Staine L,[1] Colpo GD,[2] Rocha NP,[2] Teixeira AL,[2]Ifejika N,[3] Freeman L[1]

[1]Department of Neurology and [2]Department of Psychiatry, McGovern Medical School, UTHealth, Houston, TX, USA; [3] Department of Physical Medicine and Rehabilitation, UT Southwestern, Dallas, TX, USA

Background and Purpose: Despite the recent expansion of its therapeutic arsenal, multiple sclerosis (MS) remains a leading cause of disability. Exercise has proven to be an effective non-pharmacological approach to manage deficits, and improve quality of life in people with MS. Yet, engagement in physical activity remains limited in the MS community due in part to lack of access to adaptive exercise programs. To assess the safety and impact of the Moving Stronger program, a 12-week small group based exercise program offered at the YMCA, and designed specifically for people with MS of

all ability levels. **Methods**: Moving Stronger is a 12-week, multimodal exercise program (yoga, aquatics, resistance and functional training) comprised of twice-weekly supervised sessions led by YMCA instructors, and available at no cost to participants. Instructors are trained to understand the needs and limitations of people with MS to provide a safe environment. Each session is outlined with modifications to adapt to each participant's level of ability. 11 participants with clinically definite MS (EDSS = 2.5-6.5), enrolled in the Moving Stronger program, participated in the present study. Several tests were completed pre- and post-intervention, including 6-minute walk test, timed 25-foot walk and 9-hole peg test. Patient-reported outcome (PRO) measures included MS Impact Scale 29 (MSIS-29), MS Fatigue Scale (MFIS) and MS walking scale (MSWS-12). **Results**: Comparison pre- and post-intervention showed improvement of 6-minute walk test (831.65 ft. to 1079.6 ft., P = .006). All PRO measures improved significantly: MSIS-29 (76.18 to 59.18, P = .002), MFIS (39.90 to 26.09, P = .0004) and MSWS (41.38 to 36.60, P = .026). No severe adverse events were reported. **Discussion**: Our preliminary results suggest that the Moving Stronger program is safe and may improve participants' endurance, fatigue, and symptom perception. This Moving Stronger program is uniquely scalable and has the potential to become an integral component of the MS care paradigm.

(13) Validation of Fitbit Flex2 in Multiple Sclerosis

Valerie Block V, Zhao C, Gelfand J, Cree BAC

Department of Neurology, Weill Institute for Neurosciences, University of California San Francisco, San Francisco, CA, USA

Background and Purpose: Objectively and remotely measuring physical activity in the natural environment can be useful for documenting activity status for clinical care and as an exploratory outcome measure for multiple sclerosis (MS) clinical trials. As technology advances, newer devices require validation. We aimed to determine the validity of a consumer-grade accelerometer (Fitbit-Flex2), against the older Fitbit-Flex (both wrist-worn) and ActiGraph-GT3X (waist-worn), in people with MS. **Methods:** 24 people with relapsing or progressive MS enrolled in a longitudinal observational study recording activity using a Fitbit-Flex were invited to participate in a 7-day home validation wearing the Fitbit-Flex2 and ActiGraph. Primary outcome was STEPS per epoch (average daily step count) and disability was assessed using the EDSS (expanded disability status scale). **Results:** Median EDSS at baseline was 4 (range 0.0-6.5). 12 (50%) of the cohort were women, and 12 (50%) had relapsing-remitting MS and 50% progressive MS. High Interclass correlations were found: Flex and Flex2 (0.98) and ActiGraph and Flex2 (0.90) over 1-week of continuous activity monitoring. Bland-Altman plots showed no systematic bias between Flex2 and Flex (mean difference: 237 more steps recorded by Flex2, P = .22). Bland-Altman plots showed greater number of step per day recorded by Flex2 than ActiGraph (mean difference: 1433 more steps, P < .01). Although 92% of these data were within the 95% limits of agreement. The majority

(92%) of the subjects showed no difference in wear-time for the Flex and Flex2. Accounting for MS subtype did not change the results for Flex vs. Flex 2. However, in progressive MS, ActiGraph vs. Flex 2 there was a significant mean difference (slope: 0.146, P = .027). Linear regression with Bland-Altman resulted in plots with 96% falling within the limits of agreement. **Discussion:** Preliminary data suggests STEPS can be determined in MS patients using either the Fitbit Flex or Flex2. Wrist-worn, consumer-targeted devices can be an alternative to research-grade accelerometers, predominantly for longer-term remote activity monitoring in MS. Further study is ongoing.