A NOVEL METHOD FOR IDENTIFYING WEIGHT DISTRIBUTION CHANGES DURING PROLONGED STANDING

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INTRODUCTION

A common measure in prolonged standing research includes weight distribution changes over time, measured in the form of weight shifts, fidgets, and transfers, as an attempt to contextualize how people facilitate joint load relief and increased blood flow [1-5].

The simplest analysis methods compare center of pressure (COP) or percent bodyweight (%BW) to a defined threshold [1,4]. Cham and Redfern (2001) defined weight shifts as a change of any duration in the lateral COP beyond 10% of the total COP range seen for the trial [1]. A weight shift defined by Wiggermann and Keyserling (2011) required that the subject change the distribution of bodyweight between the following groups and sustain that change for greater than 7.5 seconds: (1) >80 %BW on the left leg, (2) >80 %BW on the right leg, or (3) >20 %BW on each leg simultaneously [4]. Prado et al (2011) calculated a cumulative sum of positive and negative changes in vertical ground reaction forces between legs compared to a user defined bodyweight threshold [5].

Inconsistency across methodologies yields varying results, which tell different stories about the same data [6]. Methods in prior literature only count the number of instances that force and/or time pass a certain threshold. The proposed method uses articular cartilage viscoelastic material properties as an inspiration to differentiate fidgets and shifts using both time and %BW moving threshold components.

METHODS

Eight healthy adults (two females, six males) were screened and consented to participate in the study. Mean ± standard deviation participant demographics were as follows: age 22.5 ± 2.4 years, height 177.8 ± 11.2 cm, mass 79.9 ± 13.0 kg, BMI 25.3 ± 3.8 kg/m^2.

Two balance plates (BP5050, Bertec Corporation, Columbus OH) were used to track postural movements during standing at a sampling rate of 1000 Hz. Each subject stood with a foot on each plate for six hours and were instructed to maintain ground contact with both feet during the entire testing session. During standing, subjects were allowed to weight shift, but were not instructed to do so. A standing desk was provided so that subjects could perform a computer task.

Using Matlab, data was down sampled to 20 Hz for analysis. The force output from each plate was analyzed to investigate the weight endured by the left and right feet during standing.

The main variables of interest for this study were shifts and fidgets between states. A standing state is a maintained +/- 10 %BW on the dominant leg for >7.5 seconds. A weight shift is a change between states. A fidget is a fast movement out and back into the same state, lasting between 0.75 and 7.49 seconds. Movements lasting <0.75 seconds were eliminated as noise. Shifts and fidgets were identified computationally using Matlab. All outputs were examined by two reviewers for appropriateness of the identified events. Fidgets associated with pushing off or recoiling into another state were termed “bunny ears” (due to the shape of the curve) and were manually removed from the dataset when erroneously identified as isolated events. When fidgets were found clustered together without an appreciable change in %BW between them, one fidget was manually identified as a representative for that fidget event. Discrepancies between reviewers were discussed with a third researcher until a consensus could be reached.

RESULTS AND DISCUSSION

Subject data was used to identify shift and fidget events by the proposed method as well as shift events using the methods previously reported by Cham [1], Wiggerman [6], and Prado [7] (Table 1).

A Spearman correlation of shifts and shifts + fidgets by each method during the first and sixth hours found relationships reported in Table 2.

As expected, most methods did not result in statistically significant correlations between shifting or shifting + fidgeting events. Wiggermann's method counts extreme events also observed using the proposed method—therefore it is expected that these methods would be correlated, indicated in Table 2. Furthermore, visual observation of subject COP data indicates that shifting and fidgeting frequency and amplitude increase over time, which is detected by Prado's method, as well as the proposed method [5].

The proposed method identifies postural changes in ways similar to previously presented, but classifies them in ways that provide more information about the time and magnitude of the postural strategy used. This helps gain a better understanding of what amount of weight may be tolerated by the body before postural adjustment is initiated as well as the temporal quality of the strategy.

CONCLUSIONS

This paper describes a new method for identifying postural change events during prolonged standing. Future work may consider analyzing weight shifting strategies that individuals use to decrease discomfort over time as a means to classify subgroups of prolonged standers. Subgroup analyses can provide more appropriate between subject comparisons.

REFERENCES

[1] Cham R and Redfern MS *Human Factors: The Journal of the Human Factors and Ergonomics Society* **43**, 381-381, 2001.

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[3] Lin Y-H et al. *Applied ergonomics* **43**, 965, 2012.

[4] Wiggermann N and Keyserling WM. *Human Factors: The Journal of Human Factors and Ergonomics Society* **55**, 764-775, 2013.

[5] Prado JM, Dinato MC, and Duarte M. *Gait Posture*, **33**, 93-97, 2011.

[6] Wiltman S and Chambers A. *HFES Annual Meeting*, Austin, TX, 2017.

Table 1. Comparison of events identified in subject data using the four analysis methods.

		Hour 1					*Hour 6*				
		C:S	*W:S*	*D:S*	*P:S*	*P:F*	*C:S*	*W:S*	*D:S*	*P:S*	*P:F*
Subject #	*04*	38	3	7	7	7	178	25	12	45	8
	08	123	0	3	6	28	245	7	31	39	67
	10	280	0	4	4	21	314	0	5	0	46
	11	312	0	86	2	21	1839	3	223	10	53
	12	201	0	3	0	36	558	0	41	4	120
	13	186	7	26	35	45	676	19	46	83	78
	14	81	0	10	0	13	725	0	16	0	66
	15	179	0	5	2	9	1561	0	10	11	49

C:S – Cham:Shifts W:S – Wiggerman:Shifts D:S – Prado:Shifts P:S – Proposed:Shifts P:F – Proposed:Fidgets

Table 2. Spearman r comparing shift events at Hour 1 and Hour 6.

	Hour 1				Hour 6			
	W:S	*D:S*	*P:S*	*P:F+S*	*W:S*	*D:S*	*P:S*	*P:F+S*
C:S	-0.312	0.108	-0.193	0.381	-0.431	0.357	-0.252	0.143
W:S		0.408	0.773*	0.327		0.342	0.855*	0.152
D:S			0.152	-0.204			0.299	0.738*

C:S – Cham:Shifts W:S – Wiggerman:Shifts D:S – Prado:Shifts P:S – Proposed:Shifts P:S+F – Proposed:Shifts + Fidgets
P values > 0.05, unless indicated. * P values < 0.05

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2:30pm-4:00pm	**Parallel Session E – Controlling Movement** Moderators: Jonathan Dingwell and Tyler Richardson **Gaige 248**	**Parallel Session F – Sport and Activity** Moderators: Elisa Arch and Praveen Veerabhadrappa **Gaige 247**
2:30pm	**E1 – Choose Wisely: How Humans Regulate Lateral Stepping in Walking** Dingwell, Jonathan B.; Cusumano, Joseph P.	**F1 – Quantifying Knee Injury Risk During a Wrestling Takedown** Fox, Zachary B.; Altman-Singles, Allison R.
2:45pm	**E2 – Medial-Lateral Gait Stability in People with Transtibial Amputation Across Walking Speeds** Wedge, Ryan D.; LaPré, Andrew K.; Sup, Frank C.; Umberger, Brian R.	**F2 – Landing Characteristics Of Beanbag And Koosh Ball Throws** Meyer, Ben W.
3:00pm	**E3 – A Novel Method for Identifying Weight Distribution Changes During Prolonged Standing** Wiltman, Stephanie A.; Rekant, Julie; Chambers, April J.	**F3 – Alterations of Jump Mechanics in Dancers due to Fatigue** Hatten, Ashley E.; Altman-Singles, Allison R.
3:15pm	**E4 – Modeling Noise Regulation in a Simple Shuffleboard Machine** Cusumano, Joseph P.; Dingwell, Jonathan B.	**F4 – PNF and Static Stretching Effects on Vertical Jump Height and Loading Rate of Jump Landings** Ciccone, Arthur J.; Hatten, Ashley; Altman-Singles, Allison R.
3:30pm	**E5 – Modular Control of the Timed-Up-and-Go Test in Stroke Survivors** McDonald, Hannah D.; Allen, Jessica L.	**F5 – Biomechanical Response to Acute Patellofemoral Pain in Running** Jewell, Carl; Hamill, Joseph; Boyer, Katherine A.
3:45pm	**E6 – Virtual Air Hockey Table As Motor Control Analysis Research Platform** Bianco, Michael A.; Cusumano, Joseph P.; Mahoney, Joseph M.	**F6 – Comparison of knee biochemical variables in involved and uninvolved knees 6 months post anterior cruciate ligament reconstruction (ACLR)** Neal, Kelsey A.; Williams, Jack R.; Khandha, Ashutosh; Buchanan, Thomas S.
4:00pm-5:00pm	**Poster Session II & Coffee/Ice Cream Break** All Even-Numbered Posters **Gaige Lobby**	
5:00pm-5:30pm	**Awards & Closing** AMTI Best Student Poster Award Qualisys Best Student Podium Award **Gaige 121**	
6:30pm-9:00pm	**Optional Dinner and Social Activity** ***West Reading***	