COMPARISON OF CONCENTRIC MOVEMENT VELOCITY WITH PUSH BAND 2.0 AND VICON MOTION CAPTURE DURING RESISTANCE EXERCISES

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We compared concentric movement velocity (CMV) measured with PUSH Bands (v.2.0) and a Vicon motion capture system (Mo-cap) during back squat (SQ) and bench press (BP) resistance exercises (RE) completed using a 2-dimensional smith machine. Twelve experienced resistance-trained males completed 10 repetitions at 50% of 1-repetiton maximum (1RM), and 6 repetitions at 75% 1RM for both BP and SQ. Use of Least-squares means contrasts suggests CMV measures did not differ between measurement technologies. Also, there is no indication of systematic bias between PUSH and Mo-cap. PUSH provides an accurate and reliable measurement of CMV during moderate and high intensity SQ and BP as compared with Mo-cap.

KEYWORDS: wearable technology, concentric movement velocity, resistance exercise, strength and conditioning

INTRODUCTION: Velocity-based RE training (VBT) has gained support recently as a popular method of RE training for sport performance enhancement. The objective of VBT is to detect changes in CMV in real time (Sanchez-Moreno, Rodriguez-Rosel, Pareja-Blanco, Mora-Custodio, & Gonzalez-Badillo, 2017). Decreases in CMV during RE has been shown to be indicative of acute muscular fatigue (Pareja-Blanco, Rodriguez, Sanchez-Medina, Gorostiaga, & Gonzalez-Badillo, 2014). At present, an issue with VBT is determining an appropriate assessment technology for wide-spread use; linear transducers (LT) and Mo-cap have been shown to be valid and reliable but are cumbersome and expensive; thus impractical for use during training. Additionally, there is limited research comparing commercially available wearable technologies with established methods of assessing CMV during RE training.

PUSH Band 2.0 (PUSH) (PUSH Inc, Toronto, Canada) is a 6 axis inertial sensor that uses a 3D accelerometer, 3D gyroscope, and collects data at 1000 Hz. PUSH connects to an app on smartphones or tablets to provide CMV feedback in real time, rep-by-rep. There is little agreement in the literature on the reliability and validity of PUSH. To our knowledge, 4 published studies assessed PUSH during SQ (Balsalobre-Fernández, Kuzdub, Poveda-Ortiz & Campo-Vecino, 2015; Orange et al., 2019; Banyard, Nosaka, Sato & Haff, 2017; Hughes, Peiffer & Scott, 2019). Balsalobre-Fernández et al. (2015) suggested PUSH was valid and reliable at light to heavy loads. Orange et al. (2019) suggested PUSH exhibited moderate to high validity with poor reliability at all intensities. Banyard et al. (2017) suggested PUSH was valid only at light to moderate intensities during SQ RE. However, none of these studies compared PUSH to Mo-cap, only LT. Also, 5 published studies compared PUSH during the BP. Gold-standard devices used to compare PUSH during the BP included; LT (Orange et al., 2019; Tillaar & Bell, 2019; Hughes et al. 2019), optical motion sensing system (Perez-Castilla, Piepoli, Delgado-Garcia, Garrido-Blanca & Garcia-Ramos, 2019) and Mo-cap (Lake et al., 2019); Lake et al. (2019) suggest PUSH was reliable (ICC>0.70) with poor validity at moderate to high intensities, while Orange et al. (2019) suggested poor reliability (ICC≤0.75) and high validity (r>0.90) across all intensities. With CMV being used as an indicator for acute muscular fatigue (Pareja-Blanco et al. 2014), the primary purpose of this study was to compare measures of CMV between PUSH and Mo-cap during SQ and BP. A secondary purpose was to determine which PUSH placement site provided the most accurate measurement as compared to Mo-cap.

METHODS: Twelve experienced resistance trained males from DI colligate football and power-lifting teams volunteered to participate in this study. Anthropometric measurements were taken and body composition was assessed using bioelectrical impedance (Inbody – Company & City), as shown in Table 1.

Table 1: Physical Characteristics

Variable	Min	Max	Mean	Standard dev.
Age (years)	21.0	37.0	26.0	5.5
Experience (years)	5.0	20.0	10.7	5.6
Height (cm)	167.0	183.0	175.6	4.9
Weight (kg)	73.6	125.0	96.3	15.8
SMM (kg)	34.1	48.9	41.9	5.3
Fat mass (kg)	10.4	46.1	23.3	11.6
BMI	24.9	39.9	31.2	4.8
% Fat	13.2	36.8	23.4	8.4

Prior to the RE trials, subjects performed a standardized warm-up of cycle ergometry for 5 minutes, and then completed a personalized warm-up. Subjects were randomly assigned to perform BP or SQ, first. BP and SQ were performed in a 2D Smith Machine (BODYCRAFT-The Jones Club Maxrack), which moves vertically and horizontally. PUSH were attached to the right side of the barbell (RB), center barbell (CB), left side of the barbell (LB) and right arm (Arm). Mo-cap markers were placed on top of each PUSH. All PUSH devices were positioned as recommended by the manufacturer. A ten camera Mo-cap (Vicon Motion Systems, Oxford, UK) system was calibrated to 3,000 frames prior to each data collection session. Each subject performed 10 repetitions at 50% and 6 repetitions at 75% of self-reported 1RM, with ≥5 min rest between sets for each RE and intensity. CMV was recorded and stored on ipads from each PUSH. Data for each Mo-cap marker was recorded, stored, and exported to Microsoft Excel for analysis. Mo-cap data was exported at 100 Hz, which included each marker's displacement, velocity and acceleration. The concentric phase of each repetition was used for analysis and was defined as the time difference from the 1st positive vertical velocity to the 1st negative velocity, for each repetition. CMV was calculated as the average velocity in the concentric phase, for each repetition. Linear Mixed Model, with least-squares means post-hoc analyses was performed to compare PUSH and Mo-cap CMV, with $\alpha=0.05$. Additionally, (ICC), Mean Absolute Error (MAE), MinMax Accuracy, Mean Error (ME), and Tracking Signal (i.e., measures of bias) were used to compare PUSH and Mo-cap CMV. Tracking signal is a measure of the number of repetitions where CMV of PUSH was above or below the Mo-cap CMV. The closer the signal is to 0, the lower the bias.

RESULTS: Ninety-five percent of the total number of repetitions (384), were captured and recorded by PUSH and Mo-cap. Out of 1,536 total possible measurements recorded with PUSH, about 99% were captured and recorded. Post-Hoc testing showed there was no difference ($P>0.05$) between PUSH and Mo-cap CMV, when position, RE, intensity, and REP were incorporated into the Linear Mixed Model. In Table 2, the MAE between PUSH and Mo-cap ranged from 0.037m/s to 0.108m/s. MAE is the average error of PUSH, for each set, when compared to the Mo-cap. Accuracy for PUSH ranged from 93.9% to 84.8%. ICC ranged from 0.961 to 0.671. A two-way random effects model was chosen for ICC. Measurements of Bias between PUSH and Mo-cap suggested no systematic bias across PUSH placement, RE, or RE intensity. Mean error (ME), a measure of bias, ranged from -0.002m/s to 0.068m/s. ME is a measure of the direction of the error, averaged over the repetitions for each set, when compared to Mo-cap.

Table 2: Measures of Accuracy and Bias between PUSH and Mo-cap

			Reliability	Error	Accuracy	Bias	
RE	Intensity	Position	ICC	MAE (m/sec)	MinMax Accuracy (%)	ME	Tracking Signal
BP	50	arm	0.961	0.038	93.804	0.025	4.167
SQ	50	arm	0.931	0.052	92.930	0.006	1.250

BP	75	arm	0.936	0.037	89.655	0.007	0.636
SQ	75	arm	0.852	0.048	90.878	0.007	1.417
BP	50	CB	0.922	0.061	90.661	-0.017	-2.333
SQ	50	CB	0.955	0.045	93.909	0.035	6.200
BP	75	CB	0.890	0.054	86.140	-0.034	-3.417
SQ	75	CB	0.835	0.055	90.122	0.050	3.917
BP	50	LB	0.809	0.108	84.802	-0.034	-2.917
SQ	50	LB	0.889	0.072	91.239	0.030	5.364
BP	75	LB	0.910	0.054	86.707	-0.016	-1.083
SQ	75	LB	0.835	0.065	89.406	0.059	5.000
BP	50	RB	0.828	0.095	87.745	-0.002	-2.417
SQ	50	RB	0.894	0.058	92.660	0.031	4.083
BP	75	RB	0.867	0.047	87.737	-0.020	-2.083
SQ	75	RB	0.671	0.075	87.570	0.068	5.500

SQ=Back Squat. BP=Bench Press. RB=Right side of Barbell, LB=Left side of Barbell. CB=Center of Barbell, MAE=Mean Absolute Error, ME=Mean Error

Figure 1: CMV for SQ at 50% for Mo-cap and Push across Reps with Tracking Signal Overlay

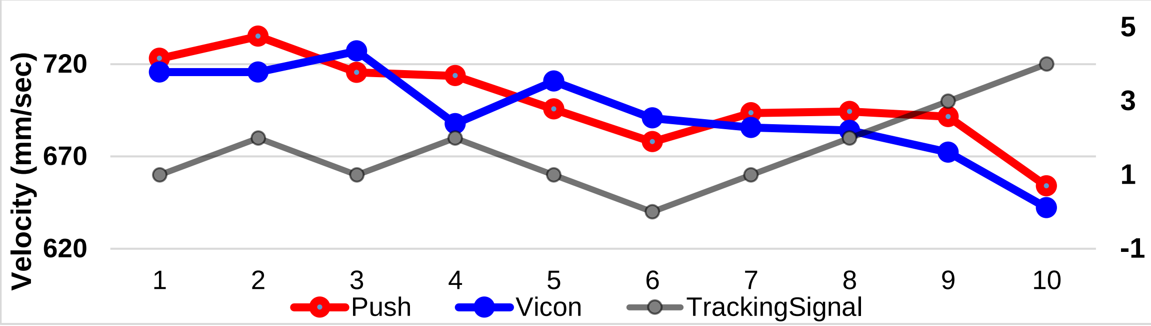

Figure 1. Represents Bias for SQ at 50%-1RM across 10 repetitions, bias would be indicated if CMV of PUSH was always above or below CMV measured with Mo-cap.

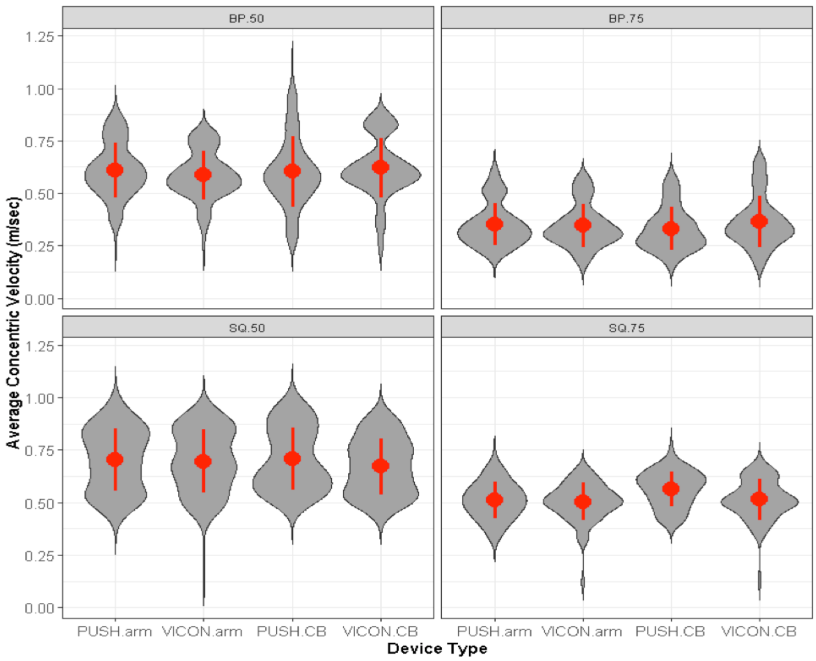

Figure 2. Represents Violin plots of PUSH vs Mo-cap for CMV measurements at specific intensities, RE, and placements.

DISCUSSION: During SQ and BP RE, PUSH provided an accurate and reliable measurement of CMV when compared to Mo-cap (See Table 2 and Figure 1). Figure 2., indicates the means and standard deviations for PUSH and Mo-cap are similar for each RE, intensity and for arm and CB placement sites. Overall, PUSH Arm and CB placement locations provided the best results; these positions exhibited the highest ICC, least MAE and indicators of bias. However, our data are not in complete agreement with other studies previously reported in the literature; this is likely a function of differences in CMV measurement methodologies. We used a 10 camera Mo-cap system with optical markers placed on each of 4 PUSH devices. CMV was compared between PUSH and Mo-cap at each placement site and across each RE type and intensity for each Rep. Previous studies have compared PUSH with LT and could not make the same type of measurement comparisons. Orange et al. (2019) and Banyard et al. (2017) used LT as the referent technology for comparison with PUSH. These data lead the researchers to conclude PUSH showed poor reliability and validity during SQ and BP across various intensities. The differences between our data and these studies are likely the result of differences in measurement methodologies. Orange et al., 2019 and Banyard et al., 2017 placed PUSH on the subject's forearm, and LT on the outside of the barbell, while Perez-Castilla et al. (2019) placed PUSH on the subject's forearm, with a single Mo-cap marker on the left side of the barbell using a Trio-OptiTrack motion sensing system. However, Lake et al. (2019) used similar a measurement methodology; they placed PUSH on the CB and a Mo-cap marker directly on top of the PUSH. Analysis of their data suggested PUSH was reliable when measuring CMV during the BP.

CONCLUSION: There was no difference between PUSH and Mo-cap CMV as a function of position, RE, intensity, and Rep. On a rep-by-rep basis, ICC and MAE suggested the PUSH Arm location most accurately measured CMV for SQ and BP as compared to Mo-cap, closely followed by the CB location. Additionally, these data were suggestive of little systematic bias. Overall, these data suggest PUSH delivers an accurate and reliable measurement of CMV when compared to Mo-cap, across position, RE, intensity, and reps.

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