Accuracy and precision of a wearable inertia sensor during a free-weight back squat

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Introduction

Wearable technology allows researchers and practitioners to collect and process real-time data in ecologically valid settings. However, before the new technology is systematically applied throughout training and competition, the scientific basis for the device must be established (3).

The PUSH™ band (PUSH Inc., Toronto, Canada) is a wearable inertial sensor that offers a small, user-friendly and affordable tool to measure movement velocity, force and power output during resistance training (1).

Previous research investigating the validity and reliability of the PUSH™ band during a back squat exercise has produced conflicting results in recreationally active participants (1, 2). More recently, Orange et al. (2018) examined the validity and reliability of the PUSH™ band during the free-weight back squat in professional male youth rugby league players. They reported good validity and reliability of the PUSH™ band only for measurements of mean and peak power at 20% of 1RM (4).

Therefore, the accuracy and precision of measurements quantified by the PUSH™ during the free-weight back squat in other athletic populations remain unclear.

Aims

The purpose of this study was to examine the error in all variables reported by the PUSH™ band in comparison to a “gold standard” criterion method of two Kistler force platforms and 3D motion capture system during the free-weight back squat.

Methods

Seven male Scottish Rugby Union academy players (age 18.8±1.2 years; height 1.84±0.08 m; body mass 96.9±11.7 kg) were recruited. Participants performed a total of 134 free-weight back squat repetitions with a mean weight of 117.5 kg (±14.72) as part of their regular training sessions. All repetitions were simultaneously captured using the PUSH™ band and two Kistler force platforms (Kistler Holding AG, Switzerland) synced with a 12 Oqus 300+ camera motion capture system (Qualisys, Sweden) sampling at 500Hz.

The PUSH™ band was worn on the participant’s right forearm as per manufacturer’s guidelines. The PUSH™ band was synced via Bluetooth with an iPad (Apple Inc, California, USA) and data was collected using the PUSH™ training app (Version 2). Participants performed the squats with one foot on each force platform. The bar was tracked via two retro-reflective spherical markers each end of the bar.

PUSH™ band, Qualisys and Kistler data were then imported into Matlab (R2014a, The Mathworks Inc., Natick, MA, USA) for the analysis of six variables: mean and peak concentric velocity (MV and PV), mean and peak concentric vertical ground reaction force (MF and PF), and mean and peak concentric power (MP and PP).

The accuracy and precision of the PUSH™ system were assessed in two ways. Bland-Altman plots were created for each variable for visual inspection. Then MANOVA and subsequent univariate tests were used to assess the difference between the systems (bias). If a significant difference existed, then bias-corrected root mean square error (RMSE) (precision) was reported for that variable.

Results

From the MANOVA there was a significant difference between the systems, $F(6,127) = 904.9$, $p<0.05$. The subsequent univariate tests also showed a significant difference between the PUSH™ band and Qualisys/Kistler for all variables. Therefore, the precision of the PUSH™ band was reported as the bias-corrected RMSE (Table 1).

Table 1. Error data for the PUSH™ band system (* denotes significant difference between systems).

	Qualisys/Kistler			PUSH™ band			Error Variables			
	Mean		SD	Mean		SD	Bias (Accuracy)		F-ratios from univariate test	Bias-corrected RMSE (Precision)
Peak Velocity (m/s)	1.05	±	0.21	0.81	±	0.15	-0.23	*	256.9	±0.17
Mean Velocity (m/s)	0.56	±	0.07	0.55	±	0.07	-0.01	*	6.9	±0.05
Peak Force (N)	2715	±	264	2920	±	351	206	*	106.7	±229
Mean Force (N)	2083	±	151	2387	±	189	303	*	1753.9	±83
Peak Power (W)	2322	±	537	1767	±	481	-554	*	217.5	±432
Mean Power (W)	1162	±	160	943	±	207	-219	*	256.9	±157

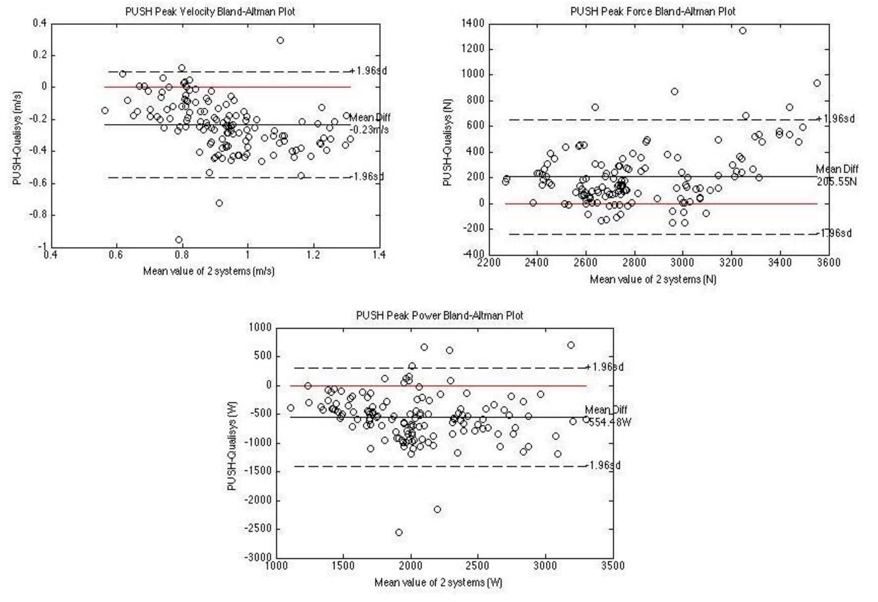

Figure 1. Bland-Altman plots for PV, PF and PP from the PUSH™ band systems all for 134 reps (redline = zero error, solid black line = mean value, dashed line = limits of agreement).

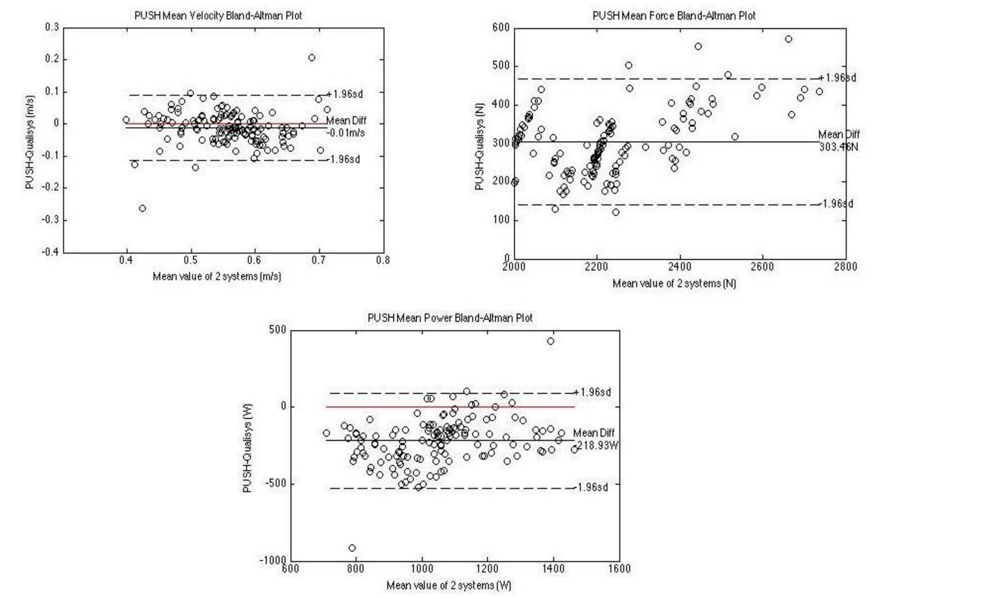

Figure 2. Bland-Altman plots for MV, MF and MP from the PUSH™ band systems all for 134 reps (redline = zero error, solid black line = mean value, dashed line = limits of agreement).

Discussion

The results showed a significant difference between the PUSH™ band and criterion system for all variables measured. Specifically, MV and PV measured by the PUSH™ band were underestimated by 0.01 m/s and 0.23 m/s, respectively. PUSH™ also underestimated MP by 219 W and PP by 554 W. In contrast, PUSH™ overestimated the MF by 303 N and PF by 206 N. The bias-corrected RMSE were calculated for MV (±0.05 m/s), PV (±0.17 m/s), MF (±83 N), PF (±229 N), MP (±157 W) and PP (±432 N). Therefore, the accuracy and precision of MV and PV variables show that PUSH™ is unlikely to categorise the movement velocities accurately. Additionally, high levels of error in MF, PF, MP and PP variables may prevent the PUSH™ band from detecting small changes in resistance training adaptations accurately and reliably. These findings contrast with previous studies that have suggested that PF (2), MV and PV (1) in back squatting could be measured reliably using the PUSH™ band. However, this is mainly due to the methodological differences, particularly the population and statistical tests used.

Overall, in agreement with a recent study (4), the PUSH™ band appears to lack the accuracy and precision to be used as a training monitoring tool in highly trained players. That said, the value of data reported by any measurement system depends on its intended use. Practitioners just need to be aware of the error in all variables reported by the PUSH™ band.

References

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