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Validity and Reliability of a Linear Position Transducer to Measure Velocity, Duration, and Displacement in the Barbell Back Squat

Ryan W. Gant[1], Anthony G. Pinzone[1], Jennifer Rivera[1], Edward Z. Pelka[1], Emily C. Tagesen[1], Modesto A. Lebron[1,2], & Adam R. Jajtner[1]

[1]*Exercise Physiology Program, Kent State University, Kent, OH, USA,* [2]*School of Kinesiology and Physical Therapy, University of Central Florida, Orlando, FL, USA*

Corresponding Author: ajajtner@kent.edu

ABSTRACT

The purpose of this investigation was to determine the validity and reliability of the Humac360 linear position transducer (LPT) as compared to Tendo Weightlifting Analyzer. Seventeen recreationally active men and women completed three visits. Visit one included maximal strength assessments via one-repetition maximum (1RM) for the barbell back squat. On visits two and three, participants completed two sets of three repetitions at 30-, 50-, 60-, and 70% 1RM. Mean Concentric Velocity (MCV), Peak Velocity (PV), Displacement (D), and Duration (T) were collected. Repetition data agreement was assessed with Intraclass Correlation Coefficients (ICCs) and were categorized as poor (<0.50), moderate (0.50 – 0.75), good (0.75 – 0.90), and excellent (>0.90). Significance was accepted at an alpha (p) value < 0.05. Repetition-to-repetition comparisons between devices demonstrate varying degrees of agreement, with significant differences between devices across all intensities and all measurements (p < 0.001). Inter-set reliability was excellent for MCV, PV, D, and T with the exceptions of MCV and PV at 70% 1RM ($ICC_{2,k}$ = 0.548 and 0.816). Inter-session reliability data demonstrated reduced agreeableness in an intensity-dependent manner, with ICCs decreasing and SEMs increasing with increases in intensity. The Humac360 LPT does not appear to be valid when compared to the criterion method, though we contend it maintains construct validity. Coaches may use the Humac360 LPT as a tool to monitor fatigue, and the associated changes in trainee movement velocity on an inter-set and inter-session basis.

Keywords: Velocity-Based Training, Autoregulation, Resistance Exercise

INTRODUCTION

Velocity-based training (VBT) is an alternative training approach that has continued to increase in popularity and is rooted in the understanding that movement velocities decrease as external loads increase in intensity or reach proximity to a one-repetition maximum (1RM) (14). Consequently, changes in velocity have been reported across differing intensities (7,13,21). As such, use of velocity as a prescriptive measure of intensity has been noted to reflect strong correlations to relative load in both maximal and submaximal intensities (4,9,11). Moreover, velocity measurement provides the opportunity to predict training intensities without accumulating volume or fatigue that may result from traditional 1RM assessments involving maximal loads (15).

VBT has gained popularity for its utilization in realtime autoregulation training models, as loads can be adjusted to meet velocity targets as fatigue and preparedness change during training (17). As a result, VBT has been shown to elicit improved training adaptations when compared to a resistance prescribed on a predetermined load relative to 1RM (2,15). These improvements in training adaptations may be a consequence of both the ability to adjust training loads during an acute training session, but also over the course of training cycles. As 1RMs should improve over the course of a training cycle, the use of VBT will also limit the need for repeated reassessment of maximal strength (3,17).

With the emerging interest and data regarding VBT, the commercial availability of linear position transducers (LPT) has continued to increase. LPTs function by the tethering of a retractable line to a piece of equipment (e.g., a barbell) to collect data on time and displacement, which can then be used to determine measures of velocity and power output (18). Though a noted limitation of LPTs is in plyometric exercise (18), the use in resistance exercise results in minimal errors after the filtering and smoothing process (11). To date, several LPTs have been developed and shown to be reliable measures of velocity (18), however, to date, no investigation has examined the validity or reliability of the HUMAC 360 (HUMAC) Linear Position Transducer (Computer Sports Medicine, Inc., Stoughton, MA), despite its use in previous literature (12). As such, the aim of this investigation was to assess the validity and reliability of the HUMAC when compared to a previously validated velocity measurement tool (TENDO; Tendo Sport, Trencin, Slovak Republic) during the back squat (10). We hypothesize the HUMAC will display strong levels of validity when compared to the TENDO, as well as excellent levels of inter-set and inter-session reliability across a range of intensities during the barbell back squat.

METHODS

Experimental Approach to the Problem

This study was designed to assess the validity and reliability of the HUMAC relative to a previously validated velocity measurement device TENDO (10). To accomplish this, participants reported to the lab for three visits separated by a minimum of 48 hours. During Visit 1, participants provided informed written consent, completed a medical history questionnaire, anthropometric assessment, and maximal strength assessment. The following two visits were identical experimental trials that consisted of two sets of three repetitions at 30%, 50%, 60%, and 70% of their previously determined one-repetition maximum (1RM) in the barbell back squat. Mean concentric velocity (MCV), peak velocity (PV), barbell displacement (D), and repetition duration (T) were collected during the protocol. Performance was assessed by the two linear transducers with both transducers secured to the medial aspect of the barbell sleeve on opposing ends of the barbell. The study overview is depicted in Figure 1.

Participants

Twenty recreationally active participants agreed to participate in this study. Three participants were removed from the final analysis due to incomplete data collection due to experiencing injury outside of the investigation (n=1), and safety concerns regarding exercise technique (n=2). Therefore, 17 individuals (12 males, 5 females; 24 ± 4 years; 1.71 ± 0.07m; 80.8 ± 11.2kg; 1.40 ± 0.40 1RM load to bodyweight ratio) were included in the final analysis. All participants provided informed written consent prior to participating in any testing, were free from physical limitations and had a minimum of six months prior resistance training experience. All participants

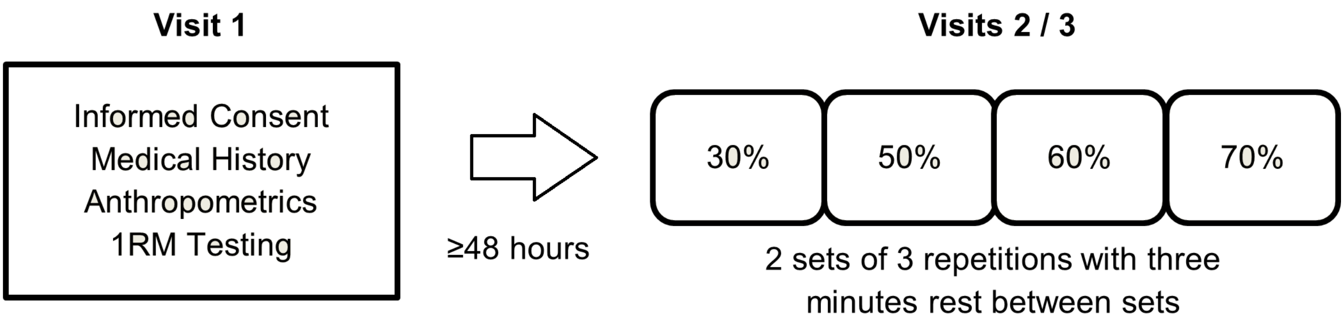

Figure 1. Study Overview. Participants reported to the Exercise Performance and Recovery Laboratory for three visits separated by at least 48 hours. During visit one, participants provided informed consent and baseline testing, while visits two and three both consisted of the experimental protocol (2 sets of 3 repetitions at 30-, 50-, 60-, and 70% of 1RM).

were instructed to abstain from caffeine for 16-hours preceding visits, as well as avoid exercise for the 24-hour period prior to each visit. All procedures utilized for this investigation were approved by the University's Institutional Review Board.

Study Procedures

Anthropometric Assessment

Participants were assessed for height (±0.5 cm) and body weight (±0.1 kg) using a Healthometer 500KL specialty scale (McCook, IL) during the initial visit.

Strength Assessment

Participants completed a standardized warm up consisting of riding a stationary ergometer (Schwinn Airdyne; Vancouver, WA) for five minutes at a self-selected pace followed by 10 bodyweight squats and 10 walking lunges. Standardized protocols were utilized to assess maximal strength (6) with warm-up sets ascending in load and descending in repetitions: one set of five to ten repetitions, followed by one set of three to five repetitions, then one set of one to three repetitions. Next, participants began 1RM attempts and were allowed a maximum of five attempts. 1RM was defined as the maximum amount of weight a participant could successfully move through the full range of motion while maintaining proper technique.

Study Visits

Prior to exercise, the height and weight of the participants were entered into the software supporting both the TENDO and HUMAC. Both linear position transducers were positioned on the floor and aligned to the bar path during the barbell back squat. At each session the HUMAC and TENDO were placed on the left and right sides of the barbell, respectively. As such, the retractable belts on both the HUMAC and TENDO were attached to the medial aspects of opposing barbell sleeves and perpendicular to the floor. Prior to the resistance exercise protocol, participants performed the previously mentioned warm-up, consisting of cycling for five minutes at a self-selected pace, 10 bodyweight squats, and 10 bodyweight lunges. Participants then completed two sets of three repetitions at each intensity (30-, 50-, 60-, and 70% of 1RM) in a sequential manner from low-to-high intensity. Between all sets of resistance exercise, participants were allotted three minutes of rest.

Data Analysis

Data collected using the TENDO was obtained with a requisite movement threshold of 15cm with a variable sampling frequency proprietary to the TENDO. The TENDO software provided PV, MCV, and D of each repetition. PV was defined as the greatest velocity attained during each repetition within a set, MCV was determined as the average velocity of each repetition within a set, and D was determined as the total distance traveled within each repetition throughout the back squat.

The HUMAC measured barbell displacement through changes in position with a retractable belt at a rate of 100Hz. Raw position data was then used to calculate movement velocity based on the change in position over the change in time within a customized excel spreadsheet (Microsoft Excel, 2016, Microsoft, Redmond, WA). The resulting velocity was then filtered using a rolling 0.10s average. Repetitions were identified once displacement exceeded 15cm, while the onset of each repetition was defined as a velocity exceeding 0.05m·s-1. Repetition filtering also consisted of a final check ensuring that concentric and eccentric phases were properly identified by positive or negative values, respectively. Once repetitions were identified, the peak velocity (PV), mean concentric velocity (MCV), displacement (D), and the duration of each repetition (T) were determined.

Statistical Analysis

Analysis of data was conducted by IBM SPSS Statistics 28 (SPSS Inc., Chicago, IL) and a customized Microsoft Excel spreadsheet. Data normality was assessed using the Shapiro-Wilk Test. Validity of the HUMAC was assessed by comparisons on a repetition to repetition against the TENDO. Validity was determined by using paired samples t-tests as well as Intraclass Correlation Coefficients (ICCs), Minimal Difference (MD), and Standard Error of Measurement as recommended by Weir (24).

Reliability of both the HUMAC and TENDO were compared while using both the average repetition (AR) – the average of all repetitions within a set - and the best repetition (BR) – the repetition with the highest MCV. Reliability of MCV, PV, D, and T were assessed using paired t-tests to identify differences between sets or sessions, while ICCs were used to assess agreement of data between sets and sessions. Inter-set analysis compared repetition data from Set 1 to Set 2 on Visit 2, whereas inter-day reliability compared the repetitions from Visit 1 to Visit 2. Repetitions for inter-day were selected by determining the repetitions with the highest MCV between sets on both visits. TENDO data was also assessed for reliability in the same fashion. ICCs were completed in the form of a two-way random effects model with single ($ICC_{2,1}$) or average measurement ($ICC_{2,k}$) and were assessed using previously categorized as poor (<0.50), moderate (0.50 – 0.75), good (0.75 – 0.90), and excellent (>0.90) (16). Significance for data analysis was accepted at an alpha (p) value < 0.05.

RESULTS

Validity

Validity data are presented in Table 1. ICCs for repetition-to-repetition comparisons were moderate for MCV across all intensities, while ICCs were good for PV across all intensities. Comparatively, ICCs for D were poor across all intensities. Paired t-tests showed significant differences between the TENDO and HUMAC as the TENDO consistently measured faster velocities in both MCV and PV, while the HUMAC measured consistently smaller displacement.

Inter-set Reliability

HUMAC inter-set AR reliability data is depicted in Table 2, while BR inter-set reliability data is displayed in supplemental Table S1. TENDO data is also displayed in supplemental Table S2. HUMAC AR data demonstrated excellent ICCs in set-to-set comparisons in MCV, PV, D, and T across all intensities with few exceptions. MCV and PV at 70% 1RM reflected moderate and good ICCs, respectively. Paired t-tests only indicated significant differences in T at 30% 1RM for the HUMAC.

BR data reflected excellent ICCs from 30% to 60% in MCV and PV with poor ICCs for both measures at 70% 1RM. D reflected excellent ICCs across all intensities. Additionally, ICCs for T ranged from good to moderate across all intensities. BR data also reflects no significant differences across any measure or intensity. Comparatively, AR and BR TENDO data reflects excellent ICCs in all variables across all intensities, with the only significant differences seen in AR PV at 60% 1RM.

Table 1. Validity Data.

		30%	50%	60%	70%
Mean Concentric Velocity ($m \cdot s^{-1}$)	$ICC_{2,1}$	0.673	0.553	0.537	0.610
	P	<0.001*	<0.001*	<0.001*	<0.001*
	MD	0.230	0.204	0.195	0.152
	SEM	0.083	0.074	0.070	0.055
Mean (Standard Deviation)	HUMAC	0.76 (0.23)	0.68 (0.17)	0.63 (0.15)	0.55 (0.14)
	TENDO	0.92 (0.19)	0.80 (0.12)	0.74 (0.11)	0.64 (0.10)
Peak Velocity ($m \cdot s^{-1}$)	$ICC_{2,1}$	0.862	0.860	0.810	0.784
	P	<0.001*	<0.001*	<0.001*	<0.001*
	MD	0.234	0.157	0.189	0.199
Mean (SD)	SEM	0.085	0.057	0.067	0.072
	HUMAC	1.33 (0.32)	1.19 (0.23)	1.13 (0.24)	1.01 (0.25)
	TENDO	1.46 (0.31)	1.29 (0.23)	1.24 (0.21)	1.13 (0.19)
Displacement (cm)	$ICC_{2,1}$	0.465	0.434	0.433	0.436
	P	<0.001*	<0.001*	<0.001*	<0.001*
	MD	14.328	14.634	14.951	16.345
	SEM	5.169	5.280	5.394	5.897
Mean (SD)	HUMAC	51.33 (9.72)	50.05 (8.95)	50.80 (8.98)	50.16 (10.08)
	TENDO	58.80 (7.27)	57.73 (7.91)	58.27 (7.99)	57.75 (8.07)

*Validity data comparing the HUMAC to TENDO on a repetition-to-repetition basis. Intraclass Correlation Coefficient (ICC); Standard Error of the Measurement (SEM); Minimum Difference (MD); Data presented as Mean (SD) for both HUMAC and TENDO. * Denotes significant differences between device measurements (p<0.05)*

Table 2. Inter-set Data

		30%	50%	60%	70%
Mean Concentric Velocity ($m\cdot s^{-1}$)	$ICC_{2,k}$	0.995	0.982	0.988	0.548
	P	0.686	0.851	0.638	0.363
	SEM	0.253	0.035	0.025	0.198
	MD	0.070	0.097	0.069	0.548
	Set 1	0.75 (0.24)	0.68 (0.17)	0.63 (0.15)	0.55 (0.14)
	Set 2	0.76 (0.24)	0.68 (0.19)	0.63 (0.15)	0.62 (0.33)
Peak Velocity ($m\cdot s^{-1}$)	$ICC_{2,k}$	0.990	0.964	0.994	0.816
	P	0.851	0.448	0.239	0.380
	SEM	0.044	0.072	0.025	0.175
	MD	0.123	0.199	0.071	0.484
	Set 1	1.32 (0.33)	1.19 (0.24)	1.12 (0.24)	1.01 (0.24)
	Set 2	1.34 (0.32)	1.17 (0.30)	1.10 (0.24)	1.06 (0.37)
Displacement (cm)	$ICC_{2,k}$	0.987	0.992	0.990	0.925
	P	0.247	0.458	0.209	0.171
	SEM	1.518	1.146	1.231	3.518
	MD	4.207	3.176	3.411	9.751
	Set 1	50.86 (9.99)	50.05 (9.02)	51.10 (8.86)	50.61 (10.00)
	Set 2	50.19 (9.23)	50.36 (9.19)	50.55 (9.44)	48.88 (9.82)
Duration (seconds)	$ICC_{2,k}$	0.951	0.834	0.932	0.939
	P	0.042*	0.475	0.832	0.830
	SEM	0.025	0.046	0.034	0.039
	MD	0.069	0.127	0.095	0.109
	Set 1	0.67 (0.11)	0.72 (0.09)	0.79 (0.08)	0.89 (0.10)
	Set 2	0.65 (0.09)	0.73 (0.08)	0.79 (0.10)	0.89 (0.12)

*Inter-set reliability data of the HUMAC. Intraclass Correlation Coefficient (ICC); Standard Error of the Measurement (SEM); Minimum Difference (MD); Data presented as Mean (SD). * Denotes significant differences between sets (p<0.05)*

Inter-day Reliability

Inter-day reliability as determined by AR data is displayed in Table 3, while BR data is depicted in supplemental Table S3. TENDO data is also displayed in supplemental Table S4. AR data for MCV reflected good ICCs for 30 and 50%, while 60 and 70% ICCs were moderate and poor, respectively. For PV, excellent ICCs were observed at 30%, 50% and 60%, while good ICCs were observed at 70% 1RM. Good ICCs were observed for D at 30%, 60%, and 70% 1RM, while moderate ICCs were observed at 50% 1RM. Moderate ICCs were observed for T at 30%, 50%, and 60% 1RM, with poor ICCs at 70% 1RM. Significant differences were observed in AR data at 50% RM for PV, D and T, as well as for T at 60% and 70% 1RM

BR data reflected good ICCs for MCV at 30%, moderate at 50 and 60%, and poor ICCs at 70%. PV maintained good ICCs from 30 to 60%, while 70% reflected poor ICCs. D reflected moderate ICCs across all intensities. ICCs for T were considered moderate from 30 to 60%, but 70% was considered poor. Significant differences were observed for D at 30 and 50%, while T had significant differences across all intensities.

AR TENDO data depicts good to excellent ICCs across all variables in all intensities, with the only significant differences seen in D at 30% 1RM. BR TENDO data good to excellent ICCs with exceptions of MCV at 70% 1RM and D at 30% 1RM. BR TENDO also showed significant differences in D at 30 and 50% 1RM.

Table 3. Inter-session Data

		30%	50%	60%	70%
Mean Concentric Velocity (m·s⁻¹)	$ICC_{2,k}$	0.827	0.833	0.742	0.448
	P	0.349	0.386	0.603	0.396
	SEM	0.092	0.079	0.080	0.198
	MD	0.255	0.220	0.221	0.549
	Day 1	0.77 (0.24)	0.70 (0.18)	0.64 (0.15)	0.63 (0.32)
	Day 2	0.80 (0.20)	0.72 (0.11)	0.66 (0.08)	0.57 (0.07)
Peak Velocity (m·s⁻¹)	$ICC_{2,k}$	0.945	0.924	0.908	0.759
	P	0.749	**0.043***	0.191	0.816
	SEM	0.118	0.074	0.087	0.186
	MD	0.327	0.205	0.242	0.514
	Day 1	1.37 (0.32)	1.21 (0.25)	1.12 (0.24)	1.08 (0.36)
	Day 2	1.38 (0.38)	1.27 (0.22)	1.16 (0.20)	1.07 (0.19)
Displacement (cm)	$ICC_{2,k}$	0.821	0.615	0.819	0.848
	P	0.067	**0.025***	0.076	0.136
	SEM	4.585	5.569	4.265	4.246
	MD	12.710	15.435	11.823	11.768
	Day 1	51.86 (9.68)	50.86 (9.18)	51.48 (9.07)	51.11 (9.79)
	Day 2	55.06 (8.93)	55.78 (7.74)	54.26 (7.83)	53.40 (7.65)
Duration (sec-onds)	$ICC_{2,k}$	0.770	0.732	0.734	0.017
	P	0.097	**0.032***	**0.027***	**<0.001***
	SEM	0.074	0.058	0.055	0.152
	MD	0.206	0.161	0.154	0.421
	Day 1	0.67 (0.10)	0.74 (0.08)	0.80 (0.09)	0.91 (0.11)
	Day 2	0.72 (0.16)	0.79 (0.12)	0.85 (0.11)	1.14 (0.19)

*Inter-session reliability of the HUMAC. Intraclass Correlation Coefficient (ICC); Standard Error of the Measurement (SEM); Minimum Difference (MD); Data presented as Mean (SD). * Denotes significant differences between sessions (p<0.05)*

DISCUSSION

The purpose of this investigation was to determine the validity of the HUMAC as compared to the TENDO, as well as evaluate reliability on an inter-set and inter-session basis. Our data indicates that the HUMAC provides reliable inter-set and inter-session comparisons for MCV, PV, D, and T at intensities up to 60%, though inter-session reliability for T was reduced at loads of 70% 1RM. Interestingly, when reliability was determined based on the best repetition rather than the average of three repetitions, consistently lower ICCs were observed in all measures and across all intensities while SEM and MD were consistently higher. To date, only one investigation has used the HUMAC as a tool to assess velocity; though this study utilized the HUMAC to determine hand speed during punching techniques (12), with no reliability data reported. As such, to our knowledge, no data regarding the validity or reliability of the HUMAC have been reported previously.

Validity comparisons of the HUMAC compared to the TENDO are dissimilar to what other investigations have reported between devices. Briefly, our investigation demonstrated a repetition-to-repetition comparison between the HUMAC and TENDO has varied levels of agreement between variables. Across intensities, however, MCV maintained moderate ICCs, while PV demonstrated good ICCs and D had consistently poor ICCs. Notably, SEMs for both MCV and PV lessened as intensity increased. The TENDO also consistently measured a faster MCV and PV, while the HUMAC consistently measured a shorter D. Prior literature has demonstrated greater validity between the TENDO and T-force Dynamic Weight Measuring System (10) or comparing a linear position transducer (GymAware) to motion capture (1). Briefly, both studies (1,10) demonstrated excellent ICCs, while Askow and colleagues (1) demonstrated SEMs that were smaller than SEMs observed in our study. Importantly, however, both prior investigations (1,10) combined all repetitions at all intensities into a singular assessment of validity, making comparisons between our investigation and prior work difficult. Moreover, the prior approach (1,10) makes it impossible to discern differences in validity measures as the intensity changes.

As linear position transducers are often used as a tool to monitor changes in velocity on an inter-set basis (22), as is observed in VBT, we sought to evaluate the inter-set reliability of HUMAC. Our data demonstrated excellent agreement from 30 to 60% 1RM, while 70% 1RM showed declines in agreeableness in measures of MCV and PV, as well as increases in SEM and MD. Data obtained with the HUMAC agrees with what previous literature observed at lower intensities, as an investigation (8) assessing the inter-set reliability of both the Vmaxpro and T-force demonstrated moderate to excellent ICCs and good to excellent ICCs, respectively. Importantly, Feuerbacher and colleagues (8) demonstrated good to excellent ICCs at all intensities (ICC = 0.832 – 0.956) while our data demonstrated reductions in ICCs at 70% 1RM. Additionally, TENDO data demonstrate high degrees of reliability, with excellent ICCs in MCV, PV, and D across all intensities. The TENDO also demonstrated consistent SEMs across intensities, whereas the HUMAC showed higher SEMs at 30% and 70% 1RM on an inter-set basis.

Previous investigations evaluating inter-session reliability demonstrated both excellent (1) and good (19) inter-session ICCs of GymAware. Askow and colleagues (1) observed excellent ICCs for both MCV and PV, and SEMs of 0.05 $m\cdot s^{-1}$ for MCV and 0.04 $m\cdot s^{-1}$ for PV, respectively. While Orange et al. (19) demonstrated minor fluctuations in ICCs across intensities, no discernible pattern was observed which contradicts our data which resulted in reduced reliability at 70% 1RM. Consequently, apart from D and T, our HUMAC data demonstrated that increased intensity resulted in increased SEMs with decreased ICCs. Comparatively, Orange and colleagues (19) observed SEMs for MCV to range from 0.03 – 0.05 $m\cdot s^{-1}$, while PV SEM ranged from 0.06 – 0.09 $m\cdot s^{-1}$, with no discernible trend across differing intensities. Conversely, TENDO inter-session data from this investigation demonstrate good-to-excellent ICCs, with a decline in agreeableness from 60% to 70% 1RM in both MCV and PV, with consistent SEMs in MCV, PV, and D – with the exception of MCV and PV at 30% 1RM. Comparatively, the HUMAC demonstrated elevated SEMs of MCV, PV, and T at 70% 1RM. Moreover, the pattern of decrements to inter-session reliability was demonstrated across both devices, suggesting potential differences in participant performances rather than differences in collected data.

As a result, the HUMAC does not appear to provide criterion referenced validity for measures of velocity in the barbell back squat when compared to TENDO, as repetition-to-repetition comparisons demonstrated significant differences in all variables across all intensities. Though this disagreement does not indicate that the HUMAC lacks validity, as the TENDO employs a variable sampling rate that suggests TENDO data collection to be speed-dependent (25), thereby soliciting further investigations against gold-standard measurements. Our investigation, however, did attempt to segment validity measures based on intensity, something that prior investigations did not do (1,10,19). Nonetheless, the HUMAC appears to provide reliable measures of MCV, PV, D, and T on an inter-set and inter-session basis – though this reliability was reduced at higher intensities for MCV on an inter-set basis, as well as MCV, PV, and T on an inter-session basis. Another possible cause to our reduced reliability was that other investigations recruited a more trained population (1,10,19), while our study only required participants to have trained for at least six months prior to the study. As both systems resulted declines in inter-session agreeableness as intensity increased, we suspect differences in reliability at higher intensities may be attributed to the differences between systems as well as the variability in resistance training experience. As such, we contend that it is preemptive to state that the HUMAC meets criterion validity, though given the moderate to good ICCs reported, we contend the HUMAC still maintains construct validity and reliably assesses MCV, PV, D and T between sets and sessions. Due to the previously mentioned constraints of device comparisons, as well as differences in sampling frequencies, future work is necessary to further discriminate differences in participant efficacy as training intensity changes.

DATA AVAILABILITY

All data available upon request to authors: Adam Jajtner ajajtner@kent.ed.

REFERENCES

1. Askow, A. T., Stone, J. D., Arndts, D. J., King, A. C., Goto, S., Hannon, J. P., Garrison, J. C., Bothwell, J. M., Esposito, P. E., Jagim, A. R., Jones, M. T., Jennings, W., & Oliver, J. M. (2018). Validity and Reliability of a Commercially-Available Velocity and Power Testing Device. Sports (Basel, Switzerland), 6(4), 170. https://doi.org/10.3390/sports6040170
2. Banyard, H. G., Tufano, J. J., Weakley, J., Wu, S., Jukic, I., & Nosaka, K. (2021). Superior Changes in Jump, Sprint, and Change-of-Direction Performance but Not Maximal Strength Following 6 Weeks of Velocity-Based Training Compared With 1-Repetition-Maximum Percentage-Based Training. International journal of sports physiology and performance, 16(2), 232–242. https://doi.org/10.1123/ijspp.2019-0999
3. Calvert TW, Banister, Eric W, Savage, Margaret V, Back, Tim. A systems model of the effects of training on physical performance. Transactions on Systems, Man, and Cybernetics. 1976;6(2):94-102.
4. Conceic¸a˜o F, Fernandes J, Lewis M, Gonzalez-Badillo JJ, Jimenez-Reyes P. Movement velocity as a measure of exercise intensity in three lower limb exercises. J Sports Sci 34: 1099–1106, 2016.
5. Dorrell, H. F., Smith, M. F., & Gee, T. I. (2020). Comparison of Velocity-Based and Traditional Percentage-Based Loading Methods on Maximal Strength and Power Adaptations. Journal of strength and conditioning research, 34(1), 46–53.
6. Earle, R. W., Baechle, T. R., & National Strength & Conditioning Association (U.S.). (2004). NSCA's essentials of personal training. Champaign, IL: Human Kinetics.
7. Enoka RM and Duchateau J. Muscle fatigue: What, why and how it influences muscle function. J Physiol 586:11-23, 2008.
8. Feuerbacher, J. F., Jacobs, M. W., Dragutinovic, B., Goldmann, J. P., Cheng, S., & Schumann, M. (2023). Validity and Test-Retest Reliability of the Vmaxpro Sensor for Evaluation of Movement Velocity in the Deep Squat. Journal of strength and conditioning
9. Garcı´a-Ramos A, Pestan˜ a-Melero FL, Pe´ rez-Castilla A, Rojas FJ, Gregory Haff G. Mean velocity vs. Mean propulsive velocity vs. Peak velocity: Which variable determines bench press relative load with higher reliability? J Strength Cond Res 32: 1273–1279, 2018.
10. Garnacho-Castaño, M. V., López-Lastra, S., & Maté-Muñoz, J. L. (2015). Reliability and validity assessment of a linear position transducer. Journal of sports science & medicine, 14(1), 128–136.
11. Harris, NK, Cronin, J, Kristie-Lee, T, Jidovtseff, B, Sheppard, J. Understanding Position Transducer Technology for Strength and Conditioning Practitioners. Strength and Conditioning Journal. 2010:32(4)66-79.
12. House, P., & Cowan, J. (2015). Predicting Straight Punch Force of Impact. Journal of the Oklahoma Association for Health, Physical Education, Recreation, and Dance, 53(1). Retrieved from http://156.110.192.75/ojs-2.4.8/index.php/OAHPERD/article/view/6296
13. Hughes LJ, Banyard HG, Dempsey AR, Peiffer JJ and Scott BR. Using load-velocity relationships to quantify training-induced fatigue. J Strength Cond Res 33:762-73, 2019.
14. Izquierdo M, Gonzalez-Badillo J, Hakkinen K, et al. Effect of loading on unintentional lifting velocity declines during single sets of repetitions to failure during upper and lower extremity muscle actions. Int J Sports Med: 718-724, 2006
15. Jidovtseff, B., Harris, N. K., Crielaard, J. M., & Cronin, J. B. Using the load-velocity relationship for 1RM prediction. Journal of Strength and Conditioning Research. 2011;25(1):267–270. https://doi.org/10.1519/JSC.0b013e3181b62c5f
16. Koo, TK, & Li, MY. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. Journal of Chiropractic Medicine, 15(2), 155–163, 2016.
17. Leveritt M and Abernethy PJ. Effects of carbohydrate restriction on strength performance. J Strength Cond Res 13:52-7, 1999. https://doi.org/10.7717/peerj.10663
18. Moreno-Villaneuva, A, Pino-Ortega, J, Rico-Gonzalez M. Validity and reliability of linear position transducers and linear velocity transducers: a systematic review. Sports Biomechanics. 2021 https://doi.org/10.1080/14763141.2021.1988136
19. Orange, S. T., Metcalfe, J. W., Marshall, P., Vince, R. V., Madden, L. A., & Liefeith, A. (2020). Test-Retest Reliability of a Commercial Linear Position Transducer (GymAware PowerTool) to Measure Velocity and Power in the Back Squat and Bench Press. Journal of strength and conditioning research, 34(3), 728–737. https://doi.org/10.1519/JSC.0000000000002715
20. Pestaña-Melero, F. L., Haff, G. G., Rojas, F. J., Pérez-Castilla, A., & García-Ramos, A. Reliability of the Load-Velocity Relationship Obtained Through Linear and Polynomial Regression Models to Predict the 1-Repetition Maximum Load. Journal of Applied Biomechanics. 2018;34(3):184-90. https://doi.org/10.1123/jab.2017-0266
21. Pick, J. Becque M.D. (2000). The Relationship Between Training Status and Intensity on Muscle Activation and Relative Submaximal Lifting Capacity During the Back Squat. Journal of Strength and Conditioning Research 14(2):p 175-181
22. Sánchez-Medina, L., & González-Badillo, J. J. Velocity loss as an indicator of neuromuscular fatigue during resistance training. Medicine and Science in Sports and Exercise. 2011;43(9)1725–1734. https://doi.org/10.1249/MSS.0b013e318213f880
23. Shattock, K., & Tee, J. C. (2022). Autoregulation in Resistance Training: A Comparison of Subjective Versus Objective Methods. Journal of strength and conditioning research, 36(3), 641–648. https://doi.org/10.1519/JSC.0000000000003530
24. Vincent, WJ and Weir, JP. Statistics in Kinesiology. 4th ed. Champaign, IL: Human Kinetics, 2012.

25. Lorenzetti, S., Lamparter, T., & Lüthy, F. (2017). Validity and reliability of simple measurement device to assess the velocity of the barbell during squats. BMC research notes, 10(1), 707. https://doi.org/10.1186/s13104-017-3012-z