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Original Research

Validity and Reliability of a Linear Position Transducer to Measure Barbell Velocity, Duration, and Displacement During the Bench Press

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ABSTRACT

International Journal of Exercise Science 17(7): 1294-1305, 2024. This investigation evaluated validity and reliability of the HUMAC360 linear position transducer (LPT) compared to the Tendo Sport Weightlifting Analyzer (TENDO) for measuring mean velocity (MV), peak velocity (PV), and displacement (D) during the bench press. Seventeen recreationally active individuals completed three visits. During visit one, participants were assessed for their one repetition maximum (1RM) bench press. During subsequent visits, participants completed two sets of three repetitions of bench press at 30, 50, 60, and 70% 1RM. The HUMAC and TENDO measured MV, PV, and D simultaneously, while the HUMAC also measured repetition duration (T). Validity of the HUMAC and inter-set and inter-day reliability for MV, PV, D, and T were assessed using Intraclass Correlation Coefficients (ICCs). The HUMAC demonstrated limited validity when compared to the TENDO as ICCs ranged from poor to good across all measurements. Significant differences were observed between devices for MV, PV, and D at all intensities ($p < 0.001$). Inter-set reliability was excellent for all intensities and measurements, but inter-day reliability was impaired for MV, PV, and D at higher intensities. Validity of the HUMAC for measuring MV, PV, and D is limited when compared to TENDO. As the HUMAC reliably assesses MV, PV, D, and T, both inter-set and inter-day (up to 60% 1RM), it may serve as an autoregulatory tool for velocity-based training.

KEY WORDS: Performance technology, resistance exercise, strength and conditioning

INTRODUCTION

Velocity-based training (VBT) is a relatively novel training approach that uses movement velocity to regulate workload and training intensity within a single resistance exercise session (5, 9). Although percentage of one repetition maximum (1RM) or estimated 1RM has traditionally been used to regulate resistance exercise intensity, 1RM can fluctuate on a day-to-day basis based on various factors such as muscular and central fatigue, psychological stress, or feelings of readiness to perform (5). Lifestyle patterns such as sleep, hydration, and nutrition are also known to affect 1RM from day to day (5). Additionally, 1RM may improve among novice athletes over the course of a few training sessions (5). Accordingly, using 1RM to assign resistance exercise intensity over the course of an extended training block is not without flaws due to its liability to change from day-to-day. As such, the use of alternative methods such as movement velocity as a prescriptive and autoregulatory measure of exercise intensity may be preferable (11). Consequently, VBT has gained popularity in both strength and conditioning and research settings (11).

Multiple different linear position transducers (LPTs) have been developed for quantifying barbell velocity from repetition to repetition. LPTs function by attaching a retractable tether to the barbell during an exercise to obtain bar displacement and duration during each repetition (4), which can then be used to determine bar velocity. One of the most commonly used devices for monitoring barbell velocity is the Tendo Sport Weightlifting Analyzer (TENDO; Tendo sport, Trencin, Slovak Republic). The TENDO has been previously demonstrated to be a valid and reliable measure for repetition velocity, displacement, and duration during the barbell bench press exercise (4). Despite the accuracy of the TENDO, however, newer LPTs have been developed in an effort to provide additional performance data. The HUMAC360 (HUMAC; Computer Sports Medicine, Inc., Stoughton, MA), another LPT, outputs repetition velocity, and displacement as well as repetition duration. The HUMAC, however, also allows for the export of raw position data at 100 Hz, affording the coach or scientist the ability to partition data within each repetition.

One investigation has used the HUMAC to assess velocity during a one-arm cable push to predict punch impact (6), but did not report any validity or reliability data. Another study (3) evaluated the validity and reliability of the HUMAC during the barbell back squat exercise and observed that the device does not display valid measures of velocity and displacement when compared to the TENDO. Their data also demonstrated that the device was reliable from set to set but noted impairments in session-to-session reliability at 70% 1RM. However, the HUMAC has not been previously validated, nor has the reliability of the device been confirmed during the barbell bench press. Assessing the validity of this device compared to the TENDO, as well as its reliability from session to session and set to set is warranted to ensure accurate data is collected through its use. Therefore, the purpose of the present investigation was to evaluate the validity of the HUMAC compared to the TENDO as well as the inter-day and inter-set reliability of the HUMAC during the barbell bench press exercise. We hypothesized that the HUMAC would display strong levels of validity when compared to the TENDO for peak and mean velocity, and bar displacement. Moreover, we hypothesized the HUMAC would reliably measure mean and peak velocity, bar displacement, and repetition duration across varying intensities on an inter-set and inter-day basis.

METHODS

To evaluate validity and reliability of the HUMAC LPT compared to the TENDO, participants completed three separate visits. During the initial visit, participants provided their informed written consent before completing a medical health history questionnaire, and anthropometric assessments. Then, participants completed a one-repetition maximum (1RM) assessment for the barbell bench press exercise. Participants returned at least 48 hours later for visits two and three, which were also separated by a minimum of 48 hours. Visits 2 and 3 consisted of a standardized warm-up and two sets of three repetitions at 30, 50, 60, and 70% of their 1RM. The HUMAC and TENDO were attached to the inside of opposing barbell sleeves and assessed peak velocity (PV), mean velocity (MV), displacement (D), and repetition duration (T). Participants were instructed to avoid exercise 24 hours prior to each visit and to abstain from caffeine for 16 hours and alcohol intake for 24 hours prior to each visit. An overview of the study design is depicted in Figure 1. All authors have complied with all ethics statements for research published in the *International Journal of Exercise Science* as detailed by Navalta, Stone and Lyons (10).

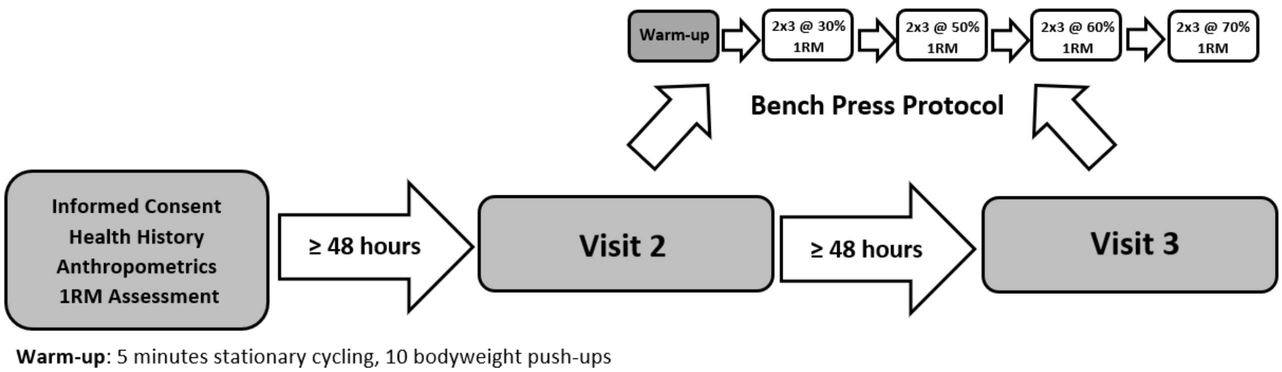

Figure 1. Study timeline. Participants reported to the laboratory for three visits: an initial visit to provide informed consent and complete preliminary testing, and two visits where the bench press protocol was performed.

Participants

Twenty recreationally active men and women with a minimum of six months of previous resistance training activity volunteered to participate in this investigation. Sample size was generated using a sample size calculator for reliability studies (1). Based on data from Gant et al. (3), a minimum acceptable intraclass correlation coefficient (ICC) of 0.6, an expected ICC of 0.9, a power of 80%, and two replicates per participants ($k = 2$) yielded a required sample size of 14. Of these 20 participants, two individuals were excluded for inability to demonstrate safe exercise technique, while one individual was excluded after sustaining an injury outside of this investigation. Therefore, final analysis was completed on seventeen individuals ($n = 12$ males/5 females; 24 ± 4 years; 1.71 ± 0.07 m; 80.8 ± 11.2 kg, 0.92 ± 0.30 relative 1RM). Exclusion criteria included any physical limitations or musculoskeletal injury reported in the previous six months. All participants provided written informed consent after a comprehensive explanation of risks and benefits associated with participation as well as the study design and procedures. This investigation was approved by the University Institutional Review Board prior to implementation.

Protocol

During their first laboratory visit, participant height, weight, and percent body fat (7) was assessed. Participant height and weight was measured using a Healthometer 500KL specialty scale (McCook, IL), while percent body fat was assessed using Lange skinfold calipers (Beta Technology, Santa Cruz, CA) using 7-site skinfold procedures previously established by Jackson and Pollock (7).

Following completion of anthropometric testing, participants were assessed for their 1RM. As this investigation was part of a larger investigation, participants were assessed for their 1RM in the back squat exercise using the same protocol (2). After completing the 1RM for the back squat, participants completed a general warm-up consisting of five minutes of cycling on a stationary ergometer (Schwinn Airdyne, Vancouver, WA) at a self-selected intensity. Participants then completed 10 bodyweight push-ups, and three warm-up sets of five to ten (50% estimated 1RM), three to five (70% estimated 1RM), and one to three repetitions (80% estimated 1RM) before having their bench press 1RM assessed (2). Participants were allowed a maximum of five attempts with three to five minutes of rest between attempts to establish 1RM, which was recorded as the maximal load that a participant could perform a successful repetition while displaying correct bench press technique. Load was increased by five to 10% between successful 1RM attempts.

Prior to each identical experimental trial (Visits 2 and 3), participants were instructed to abstain from strenuous exercise for 24 hours as well as caffeine for 16 hours and alcohol for 24 hours. After reporting to the laboratory, participants completed a squat protocol in the same fashion as the bench press, as described below. Upon completion of the squat protocol, participants completed a general warm-up protocol identical to the warm-up prior to 1RM assessment. Participants then completed the bench press protocol which consisted of two sets of three repetitions on the barbell bench press at 30, 50, 60, and 70% 1RM in an ascending order with each set interspersed by three minutes of rest. Participants were instructed to pause following the eccentric portion of the movement and complete the concentric portion of each repetition as rapidly as possible after a cue from a researcher. Participants were also instructed to reach full elbow extension during all repetitions. The retractable belts of both the HUMAC and TENDO were attached inside the medial ends of the barbell sleeves on opposing sides of the barbell and sampled bar displacement (HUMAC) or velocity (TENDO) with each repetition. Both devices were placed adjacent to the rack so that they were in alignment with the bar path of the participant during each repetition and perpendicular to the floor.

The TENDO identified each repetition as a bar displacement exceeding a minimum threshold of 15 cm at a sampling rate that varied based on velocity. The TENDO evaluated PV, MV, and D, but not T. PV was the maximum bar velocity that was reached during a repetition, while MV was the average velocity throughout the entire repetition. D referred to barbell displacement from the onset of each repetition to the cessation of each repetition, respectively.

The HUMAC measured bar displacement at a sampling rate of 100 Hz with the raw displacement data exported to a customized Excel spreadsheet (Microsoft Corporation, Redmond, WA). Changes in bar displacement over time were used to determine velocity, which was then filtered using a 0.10s rolling average. Repetitions were identified by the HUMAC when displacement exceeded 10 cm, while the repetition onset was defined as a filtered velocity exceeding 0.05 $m \cdot s^{-1}$. T was identified as the total time elapsed during the entirety of each repetition.

Statistical Analysis
All statistical tests were performed using SPSS software version 28.0 (IBM, Chicago, IL) and Microsoft Excel. After assessing the data for normality using a Shapiro-Wilk test, validity and reliability analyses were conducted. To assess validity of the HUMAC compared to the TENDO for PV, MV, and D, values obtained by each device were compared on a repetition-to-repetition basis for all sets on both days at each intensity. All individual values for each repetition and measurement at each intensity were imported for analysis when generating ICCs (e.g., HUMAC repetition one, set one at 30% 1RM to TENDO repetition one, set one at 30% 1RM).

Reliability of MV, PV, D, and T from both the HUMAC and TENDO were determined in an inter-set and inter-session fashion. Measurements were compared using an average repetition (AR) or best repetition (BR) approach. For inter-set reliability, the average of all repetitions from set one to set two were compared for AR for each intensity. Additionally, the BR for each set was noted as the repetition with the greatest MV. The BR from sets one and two were compared across all intensities for inter-set reliability as well. For inter-session reliability, MV, PV, D, and T was assessed from the BR of either set from visit 2 compared to visit 3 at all intensities. For AR, the set that produced the highest MV (set 1 or set 2) during visit 2 was compared to the set with the highest MV from visit 3 at all intensities.

For both validity and reliability analyses, paired samples *t*-tests and ICCs were determined. Paired samples *t*-tests were used to assess differences between devices, sets or sessions. Cohen's *d* was generated for effect size using the standard deviation of differences of each set, day, or device. ICCs were calculated at the 95% confidence interval using an absolute agreement, two-way random effects model (model two) with single ($_{2,1}$) or average ($_{2,k}$) measures to assess the consistency of measurement according to the recommendations of Vincent and Weir (14). ICCs were categorized as poor (< 0.50), moderate (0.50–0.75), good (0.75–0.90), and excellent (> 0.90) according to previously published standards (8). Finally, paired samples *t*-tests were used to identify constant error between devices, sets or sessions. Significance was accepted at an alpha (p) level ≤ 0.05 for all analyses.

RESULTS

Repetition to repetition validity data are displayed in Table 1. ICCs fluctuated from poor to good between intensities with no discernable pattern, however, ICCs for MV and PV tended to be stronger than for D. Moreover, significant differences were observed between devices at all intensities for all variables. MV and PV were faster when measured by the TENDO versus the HUMAC, while the displacement was consistently greater in the TENDO when compared to the HUMAC.

Table 1. Validity data.

		MV (m/s)	PV (m/s)	D (cm)
30%	$ICC_{2,1}$	0.556	0.764	0.453
	SE_M	0.268	0.219	5.913
	MD	0.30	0.30	6.30
	p	< 0.001*	< 0.001*	< 0.001*
	d	1.716	1.112	1.808
Mean (SD)	TENDO	0.91 (0.22)	1.33 (0.33)	41.94 (5.32)
	HUMAC	0.71 (0.17)	1.16 (0.29)	36.13 (4.28)
50%	$ICC_{2,1}$	0.443	0.536	0.384
	SE_M	0.157	0.179	6.069
	MD	0.20	0.27	6.08
	p	< 0.001*	< 0.001*	< 0.001*
	d	1.337	0.956	2.014
Mean (SD)	TENDO	0.76 (0.16)	1.08 (0.20)	41.96 (5.16)
	HUMAC	0.62 (0.10)	0.95 (0.14)	35.71 (3.64)
60%	$ICC_{2,1}$	0.353	0.499	0.382
	SE_M	0.136	0.163	6.195
	MD	0.16	0.24	5.88
	p	< 0.001*	< 0.001*	< 0.001*
	d	1.642	1.055	2.165
Mean (SD)	TENDO	0.68 (0.12)	0.94 (0.18)	42.09 (4.99)
	HUMAC	0.55 (0.08)	0.80 (0.11)	35.32 (3.97)
70%	$ICC_{2,1}$	0.446	0.611	0.348
	SE_M	0.103	0.126	5.918
	MD	0.13	0.19	6.38
	p	< 0.001*	< 0.001*	< 0.001*
	d	1.364	0.961	1.844
Mean (SD)	TENDO	0.55 (0.10)	0.76 (0.16)	41.59 (4.48)
	HUMAC	0.46 (0.07)	0.66 (0.11)	35.59 (3.90)

ICCs and *t*-test results displaying validity of the HUMAC compared to the HUMAC = HUMAC360, linear position transducer; TENDO. TENDO = Tendo sport weightlifting analyzer; MV = mean velocity; PV = peak velocity; D = displacement; ICC: intraclass correlation coefficient; SE_M: standard error of the measurement; MD: minimal difference; SD: standard deviation; *d*: Cohen's *d* effect size. * $p \leq 0.05$.

Inter-set reliability characteristics for AR for the HUMAC are displayed in Table 2. As reliability tended to be better with AR, BR data for the HUMAC are displayed in Table S1. Excellent ICCs were observed for AR at all intensities and measurements. No significant differences from set to set were observed at any intensities with data analyzed by the AR. ICCs for BR ranged from good to excellent for MV, PV, D, and T. Moreover, significant differences were observed for PV at 30% and 60% as well as MV at 60%, though the absolute differences between each set was less than both the MD and SE_M.

Table 2. Inter-set reliability.

		MV (m/s)	PV (m/s)	D (cm)	T (s)
30%	$ICC_{2,k}$	0.950	0.959	0.968	0.924
	SE_M	0.049	0.075	0.935	0.042
	MD	0.12	0.17	2.71	0.09
	p	0.590	0.450	0.903	0.270
	d	0.480	0.546	0.030	0.661
Mean (SD)	SET 1	0.70 (0.16)	1.15 (0.28)	35.99 (3.85)	0.54 (0.12)
	SET 2	0.73 (0.14)	1.20 (0.25)	35.95 (3.54)	0.51 (0.10)
50%	$ICC_{2,k}$	0.971	0.972	0.959	0.976
	SE_M	0.025	0.035	1.056	0.022
	MD	0.07	0.14	2.97	0.06
	p	0.285	0.494	0.513	0.370
	d	0.287	0.181	0.173	0.226
Mean (SD)	SET 1	0.62 (0.10)	0.95 (0.14)	35.71 (3.55)	0.58 (0.10)
	SET 2	0.61 (0.11)	0.94 (0.16)	35.44 (3.78)	0.59 (0.10)
60%	$ICC_{2,k}$	0.965	0.919	0.945	0.984
	SE_M	0.019	0.041	1.214	0.017
	MD	0.05	0.10	3.13	0.05
	p	0.232	0.068	0.193	0.850
	d	0.301	0.475	0.329	0.046
Mean (SD)	SET 1	0.54 (0.07)	0.81 (0.10)	35.46 (3.85)	0.66 (0.10)
	SET 2	0.54 (0.08)	0.78 (0.10)	35.02 (3.29)	0.66 (0.10)
70%	$ICC_{2,k}$	0.931	0.945	0.950	0.926
	SE_M	0.021	0.030	1.108	0.033
	MD	0.06	0.08	3.14	0.08
	p	0.453	0.501	0.663	0.173
	d	0.192	0.173	0.112	0.338
Mean (SD)	SET 1	0.46 (0.06)	0.67 (0.10)	35.77 (3.78)	0.78 (0.09)
	SET 2	0.46 (0.05)	0.66 (0.09)	35.95 (3.23)	0.80 (0.08)

ICCs and *t*-test results displaying AR inter-set reliability of the HUMAC. AR: average repetition; HUMAC = HUMAC360, linear position transducer; MV = mean velocity; PV = peak velocity; D = displacement; T = repetition duration; ICC: intraclass correlation coefficient; SE_M: standard error of the measurement; MD: minimal difference; SD: standard deviation; *d*: Cohen's *d* effect size. * $p \leq 0.05$.

Inter-set reliability statistics for the TENDO are presented in Table S3. Data indicated that the TENDO also displayed excellent AR inter-set ICCs for all measurements at all intensities. However, paired samples *t*-tests revealed significant differences for MV at 30% and PV at 30% and 60%. The TENDO also displayed good inter-set ICCs for BR for all measurements with the exception of D at 60% where an excellent ICC was observed. Significant differences from set to set were noted for MV and PV at 30%.

Inter-day reliability characteristics for AR for the HUMAC are presented in Table 3. As reliability data tended to be stronger for AR, BR data is displayed in Table S2. Excellent ICCs were observed for AR at 30% for all variables. At 50% excellent ICCs were noted for MV, while good ICCs were observed for PV, D, and T. ICCs at 60 and 70% ranged from poor to moderate for MV, PV, and T, while excellent ICCs were observed for D. A significant difference was observed between sessions for PV at 50%, though no other differences were observed for AR.

For BR for the HUMAC, ICCs ranged from good to excellent for all measurements at 30%. At 50%, moderate to good ICCs observed for MV, PV, and T, while excellent ICCs were observed for D. Poor ICCs were observed for MV, PV and T at both 60 and 70%, while good ICCs were observed for D. A significant difference between sessions was observed for PV at 50% and 70%, though no other significant differences were observed.

Inter-day reliability statistics for the TENDO are presented in Table S4. Excellent ICCs were observed for all measures at 30% AR. Good ICCs were displayed for AR MV and PV 50, 60 and 70%, while ICCs for D were excellent across all intensities. Significant differences were observed between days MV and PV at 70% AR. ICCs for BR were more variable. All measurements at 30% displayed good ICCs. Intensity-related declines in reliability were noted for the TENDO as well with moderate reliability observed for MV and PV at 50, 60, and 70%. ICCs for D were remained consistent, with ICCs categorized as good at 50, 60, and 70% BR. Paired samples *t*-tests revealed significant differences between days for MV and PV at 70% BR as well.

Table 3. Inter-day reliability.

		MV (m/s)	PV (m/s)	D (cm)	T (s)
30%	$ICC_{2,k}$	0.946	0.953	0.920	0.914
	SE_M	0.046	0.078	1.600	0.048
	MD	0.13	0.21	4.38	0.14
	p	0.878	0.292	0.497	0.740
	d	0.039	0.273	0.174	0.085
Mean (SD)	DAY 1	0.74 (0.14)	1.21 (0.24)	36.56 (3.61)	0.54 (0.12)
	DAY 2	0.74 (0.14)	1.24 (0.26)	36.95 (4.34)	0.54 (0.11)
50%	$ICC_{2,k}$	0.922	0.834	0.897	0.808
	SE_M	0.035	0.078	1.729	0.061
	MD	0.10	0.16	3.89	0.16
	p	0.836	**0.013***	0.059	0.984
	d	0.055	0.682	0.531	0.005
Mean (SD)	DAY 1	0.63 (0.10)	0.93 (0.15)	36.20 (3.47)	0.60 (0.10)
	DAY 2	0.64 (0.08)	0.99 (0.11)	37.25 (4.05)	0.60 (0.10)
60%	$ICC_{2,k}$	0.547	0.466	0.921	0.731
	SE_M	0.060	0.093	1.467	0.065
	MD	0.14	0.19	3.65	0.17
	p	0.278	0.086	0.151	0.931
	d	0.281	0.459	0.378	0.022
Mean (SD)	DAY 1	0.55 (0.07)	0.82 (0.10)	36.28 (3.96)	0.67 (0.10)
	DAY 2	0.57 (0.05)	0.86 (0.07)	36.99 (3.33)	0.67 (0.08)
70%	$ICC_{2,k}$	0.549	0.627	0.938	0.494
	SE_M	0.043	0.070	1.096	0.087
	MD	0.10	0.15	2.94	0.20
	p	0.453	0.061	0.328	0.469
	d	0.192	0.507	0.253	0.021
Mean (SD)	DAY 1	0.47 (0.06)	0.68 (0.09)	36.44 (3.45)	0.81 (0.09)
	DAY 2	0.48 (0.03)	0.72 (0.06)	36.82 (2.72)	0.79 (0.09)

ICCs and *t*-test results displaying AR inter-day reliability of the HUMAC. AR: average repetition; HUMAC = HUMAC360, linear position transducer; MV = mean velocity; PV = peak velocity; D = displacement; T = repetition duration; ICC: intraclass correlation coefficient; SE_M: standard error of the measurement; MD: minimal difference; SD: standard deviation; *d*: Cohen's *d* effect size. * $p \leq 0.05$.

DISCUSSION

To date, only two investigations have utilized the HUMAC to measure movement velocity. House and Cowan (6) used the HUMAC to measure straight punch velocity, but did not report validity or reliability data, while a prior investigation from our lab (3) evaluated the validity of the HUMAC compared to the TENDO as well as the inter-set, and inter-day reliability of the HUMAC during the squat. Therefore, no investigation has previously established the validity or reliability of the HUMAC during the bench press exercise. Overall, our data demonstrate variable validity throughout all measurements and across all intensities in MV, PV, and D when comparing the HUMAC to the TENDO during the bench press exercise, contrary to our hypothesis. The HUMAC did, however, consistently display excellent inter-set reliability for measures of MV, PV, D, and T ultimately in line with our hypothesis. However, inter-day reliability was reduced at higher intensities, contrary to our hypothesis as well (≥ 60% 1RM).

The initial aim of this project was to establish validity of the HUMAC compared to the TENDO during the bench press. We observed moderate to good ICCs for PV, with higher ICCs at lower intensities (30 and 50% 1RM), while ICCs for MV were variable, ranging from poor to moderate with no discernable pattern between intensities. Moreover, poor ICCs were observed across all intensities for D when compared to TENDO. Importantly, the HUMAC consistently reported slower MV and PV as well as smaller D when compared to the TENDO. The prior investigation from our lab (3) evaluating the validity of the HUMAC during the squat demonstrated ICCs ranging from moderate to good for MV, PV, and T, suggesting improved validity for the HUMAC during the squat, potentially resulting from a larger bar displacement and greater number of samples when compared to the bench press. Notably, however, Gant et al. (3) did observe poor ICCs for D across all intensities and that the HUMAC did consistently output slower MV and PV, and shorter D when compared to the TENDO, comparable to the present study. Therefore, validity of the HUMAC is limited when compared to TENDO; this may stem from potential constant error between the two devices.

Prior work assessing the validity of the TENDO during the bench press demonstrated excellent ICCs for MV, PV, and power when compared to a force platform (4). While the present study may indicate that the HUMAC has limited validity compared to the TENDO, it is important to note that Garnacho-Castaño and colleagues (4) utilized a smith machine, which likely minimized extraneous movement, possibly improving the validity. Additionally, Garnacho-Castaño et al. (4) combined all repetitions across all intensities when calculating ICCs, only presenting one statistic for each measurement, making direct comparisons to our investigation challenging. We contend, however, that our approach is preferrable as it allows for isolation of the validity at specific intensities.

Due to the use of VBT as a popular tool for autoregulation within a resistance exercise session (5, 11), we also aimed to establish inter-set reliability of the HUMAC and observed excellent ICCs for all measures and intensities. No significant differences were observed between sets, and no established pattern in SE_M or MD was discernable between intensities. While no prior papers have evaluated inter-set reliability of an LPT during the barbell bench press, Gant et al. (3) demonstrated excellent inter-set ICCs for MV, PV, D, and T while using the HUMAC during a back squat, though when the intensity reached 70% 1RM, ICCs were moderate for MV. It is also important to note that our study also assessed inter-set reliability of the TENDO, indicating excellent ICCs for MV, PV, and D across all intensities. Therefore, our data demonstrated that both the HUMAC and TENDO reliably assesses MV, PV, and D within sets and our findings display agreement with a previous investigation evaluating inter-set reliability of the HUMAC (3). As load is typically adjusted from set to set when VBT is employed within a session (9), it may be beneficial to establish inter-set reliability of previously-validated LPTs due to the paucity of literature in this area.

Interestingly, when reliability was assessed between days, an intensity-dependent decrease in ICCs for MV, PV, and T was noted with good to excellent ICCs at 30 and 50% 1RM and poor to moderate ICCs at 60 and 70% 1RM, though D resulted in good to excellent ICCs across all intensities. No discernible pattern was observed for SE_M or MD across intensities for any measurement. Data regarding inter-day reliability of the TENDO from the present investigation demonstrated excellent ICCs for MV and PV at 30% and good ICCs for these measurements at 50, 60, and 70% 1RM, while ICCs for D remained excellent across all intensities. Previous investigations (4, 13) examining inter-day reliability of the TENDO during the bench press have demonstrated moderate to excellent ICCs for MV and PV with no discernable pattern between intensities. Interestingly, Stock et al. (13) observed increases in proportional SE_Ms at greater experimental intensities (70–90% 1RM), suggesting greater variability as intensity increased, lending some support to the findings from our study. Similarly, Orange and colleagues (12) observed moderate to good ICCs for MV and PV when evaluating inter-day reliability of the GymAware, with SE_Ms remaining constant between 40 and 90% 1RM, contrary to our data where decrements in reliability were observed at intensities at or exceeding 60% 1RM. While examining inter-day reliability with the HUMAC during the squat, Gant et al. (3) observed similar findings to our investigation with reduced reliability at higher intensities, though no discernable change in reliability was evident until 70% 1RM, rather than 60% 1RM.

While the HUMAC appears to have limited validity for MV and PV when compared to the TENDO during the bench press, a strength of our analysis was that we reported reliability statistics at each intensity. This approach allows for greater sensitivity in observing fluctuations in velocity across intensities, which cannot be done with prior investigations (4, 12). It is also important to note that previous investigations have included more heavily resistance-trained populations when compared to the present study (4, 12, 13). We suspect that our reduction in reliability may be due to a reduced training status for our participants when compared to prior literature (4, 12, 13). Consequently, future work that evaluates validity and reliability of the HUMAC during the bench press should recruit a more trained population to assess whether the training status is responsible for our observed decrements in reliability from day-to-day at higher intensities.

Due to consistent differences observed between both devices, strength coaches should consistently utilize the same device for all measurements if using the HUMAC or TENDO as a an autoregulatory tool for velocity-based training. The ability of the HUMAC to reliably assess MV, PV, D, and T from set to set and day to day up to 60% 1RM suggests that the device can successfully monitor changes in velocity driven by fatigue or daily fluctuations in performance.

In conclusion, the HUMAC reliably measures MV, PV, D, and T from set to set and from day to day at lower intensities (30 and 50% 1RM), though was not valid based on comparisons to TENDO. Further work is necessary to establish validity of this device to a criterion in a more trained population.

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