International Journal of EXERCISE SCIENCE

Original Research

Validity, Reliability, and Sensitivity of a Commercially Available Velocity Measuring Device When Performing Selected Exercises

DANIEL J. LAWSON‡[1,4], ALEX A. OLMOS‡[1,5], CODY A. STAHL†[1], MARCEL LOPES DOS SANTOS‡[1,2], JACOB R. GOODIN‡[3], and J. JAY DAWES‡[1]

[1]Department of Kinesiology, Applied Health and Recreation, Oklahoma State University, Stillwater, OK, USA; [2]Department of Kinesiology and Recreation, Illinois State University, Normal, IL, USA; [3]Department of Kinesiology, Point Loma Nazarene University, San Diego, CA, USA; [4]Warrior Research Center, Auburn University, Auburn, AL, USA; [5]Department of Molecular Biology & Chemistry, Christopher Newport University, Newport News, VA, USA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 17(4): 1250-1279, 2024. The aim of this study was to determine the validity, reliability, and sensitivity of a new linear position transducer (LPT) device (RepOne) to a previously validated LPT (Tendo) during the barbell back squat and bench press exercises. Fourteen recreationally resistance-trained individuals (7 males and 7 females) performed three repetitions for the back squat and bench press at loads ranging from 30–90% 1RM. Both devices recorded average (ACV) and peak (PCV) concentric velocities concurrently for every repetition at each load. Significant correlations were observed between RepOne and Tendo during the back squat (PCV: $r = 0.90–0.99$, $p < 0.01$; ACV: $r = 0.84–0.99$, $p < 0.01$), bench press (PCV: $r = 0.74–0.99$, $p < 0.01$; ACV $r = 0.81–0.99$, $p < 0.01$). ICCs reveal good to excellent reliability between devices for back squat (PCV, 0.85–0.99; ACV, 0.83–0.99) and bench press (PCV, 0.79–0.99; ACV, 0.83–0.99). Bland-Altman plots revealed greater bias during PCV for both exercises across intensities (back squat, 0.072 to 0.110 m/s; bench press, 0.039 to 0.107 m/s), although ACV bias was lower for both exercises (back squat, −0.002 to −0.029 m/s; bench press, −0.022 to 0.015 m/s). The RepOne device generally exhibited higher smallest detectable change (SDC) values compared to the Tendo, except for specific loads in certain conditions. Additionally, the RepOne device demonstrated higher smallest worthwhile change (SWC) values than the Tendo unit for most loads in back squat ACV. Collectively, the RepOne exhibits strong validity and reliability comparable to the Tendo across both barbell back squat and bench press exercises, despite some variations in sensitivity metrics like SDC and SWC, indicating its efficacy for resistance training application.

KEY WORDS: Velocity-based training, accuracy, repeatability, agreement, encoders

INTRODUCTION

Velocity-based training (VBT) has become an increasingly popular method of training in recent years. This technique uses barbell velocity zones to prescribe individual resistance training loads rather than a percentage of the one repetition maximum (1RM) (12, 37). In VBT the training load is typically prescribed based on the average concentric velocity (ACV; the average velocity from the start of the concentric phase to the maximum height of the bar or end range of motion), sometimes referred to as mean concentric velocity, or prescribed as peak concentric velocity (PCV; the maximum instantaneous velocity achieved during the concentric phase of a movement) (13). These metrics (i.e., ACV and PCV) allow coaches and athletes to benchmark daily readiness against historical load-velocity relationships, which provides both real-time feedback and allows for training adjustments based on daily fluctuations in physical preparedness (33, 37). It has been postulated that these micro-adjustments in training load may facilitate greater short- and long-term adaptions and reduce risk of overtraining (22, 27, 37, 40).

Optimal VBT programming, load prescription and management, and potentially the athlete's adaptive response to training hinges on the validity and reliability of the measurement device utilized. Pareja-Blanco et al. (30) found that small changes in velocity over the course of a set can signify practically significant fatigue-induced changes in neuromuscular and functional performance. Other research describing the load-velocity relationship for various resistance training exercises observed that changes ranging from 0.05 to 0.10 m/s in the bench press and full squat on a Smith machine could represent a 5% 1RM improvement (23, 31).

These findings point to a need for VBT devices with high degrees of sensitivity. Recent efforts have employed more robust statistical methods to assess VBT device suitability by reporting standard error of the measurement (SEM) and smallest detectable change (SDC) in addition to interpreting Bland-Altman plots and correlation-based agreement measures (9). The SEM quantifies how scores on an assessment tend to deviate from the true score due to inherent error in the measurement technique and is, therefore, also an estimate of precision and reliability. The SEM is calculated by multiplying the standard deviation by the square root of one minus the reliability of the test (38). The SDC (also known as the minimal detectable change) is a mathematically-derived error band around the observed measure constructed from the SEM and the *z*-score associated with the desired level of confidence. Typically, that is the 95% confidence interval and therefore SDC is calculated as SEM multiplied by 1.96 times the square root of 2. The square root of 2 is used to model error in both the baseline score and the change score (39). Another similar statistic—the smallest worthwhile change (SWC), which is often used in the field of sport science— refers to the smallest change in an outcome measure that would be considered practically significant in a sporting or training context (34). It is often calculated as the standard deviation of a set of measures multiplied by 0.2, to represent the magnitude for a small effect size, or a threshold for SWC is set using empirical observations from context-specific data (5, 18). Therefore, SDC and SWC analyses are critical to VBT for the establishment of thresholds that constitute a meaningful change in achieved ACV or PCV (signal) versus trivial day-to-day variance in athlete readiness or device measurement error (noise). The need to detect velocity changes necessitates a device with enough accuracy to ensure that the observed changes are indicative of genuine performance improvement rather than measurement error (34). If the error of measurement for a VBT device is greater than practically significant performance changes, it could be concluded that the device is not well-suited to meet the needs of a VBT program.

A variety of technologies to measure barbell velocity exist, such as linear position transducers (LPTs), inertial measurement units (IMUs), and applications via smartphones (35). Previous research has investigated and compared the validity and reliability of these velocity-measuring devices (3, 9, 11, 14, 15, 32, 35). The current literature suggests that LPTs provide the greatest degree of validity and reliability when compared to other technologies (25, 35, 37). LPTs quantify velocity using draw wire encoders, calculating displacement over time, or estimate velocity directly from a calibrated voltage output produced from a rotating spool (25). Some limitations of LPTs include their inability to account for horizontal barbell displacement trajectories during vertical movements such as most free-weight barbell exercises (1, 25). However, it has been previously suggested that LPTs should be considered the gold standard in the field of assessing barbell velocity (2, 4, 29). Lorenzetti et al. (20) reported strong correlations when comparing the Tendo Weightlifting Analyzer (Tendo) to 3D motion capture for ACV (r = 0.963) and PCV (r = 0.932) during a barbell back squat (back squat) exercise (2 sets x 5 reps at 70% of 1RM with 3-minutes of rest between sets). Research by Goldsmith et al. (15) compared the validity and reliability of the Open Barbell System to Tendo and 3D motion capture (Optotrak Centus 3-dimensional motion capture system) during one set to volitional failure at 70% of the subject's back squat 1RM. No statistically significant differences in ACV were detected between the three devices (p = 0.089); however, significant differences in PCV between the Open Barbell System and Tendo were observed (p = 0.001). When compared to 3D motion capture, the reported intraclass correlation coefficients (ICCs) between the two LPTs were slightly greater in the Open Barbell System for ACV (Open Barbell System: 0.9364; Tendo: 0.8696) and PCV (Open Barbell System: 0.9362; Tendo: 0.8351); 95% confidence intervals (CI) for PCV were comparatively smaller for Open Barbell System (Open Barbell System: 0.9220–0.9476; Tendo: 0.5906–0.9250). Both Tendo and Open Barbell System reported larger mean bias and limits of agreements for PCV (−0.07–0.15 m/s^{-1}) compared to ACV (−0.03 to 0.04 m/s^{-1}). Collectively, these findings reinforce that LPTs (i.e., Tendo, Open Barbell System, GymAware) are valid and reliable devices that can be utilized by practitioners and athletes for measuring bar velocity.

With the increased popularity of VBT, it is probable that new devices and technologies for measuring barbell velocity will continue to emerge. Consequently, determining the validity, reliability, and sensitivity of new LPTs is essential to ensure the accuracy of the data utilized for guiding resistance training program design. To the authors' knowledge, no study has yet investigated the validitiy, reliability, or sensitivity of the RepOne 3D Motion Sensor (RepOne) against other LPT devices. Therefore, the aim of this study was to determine the validity, reliability, and sensitivity of the RepOne in comparison to the Tendo during the barbell back squat and barbell bench press exercises. The investigators also sought to determine if there were significant variations for the RepOne measurements of ACV and PCV between testing days and to provide practitioners with data concerning sensitivity to change in each device. It was hypothesized that the RepOne would provide similar ACV and PCV measurements, as well as comparable reliability (test-retest) and sensitivity metrics, compared to a previously validated device (i.e., Tendo).

METHODS

Participants

Sixteen recreationally resistance-trained individuals participated, and 14 subjects' data were included in this report. After completing the initial 1RM testing, two subjects were withdrawn from the study due to persistent scheduling conflicts that prevented them from attending the subsequent two visits. Recreationally resistance-trained individuals in this study are defined as those who have engaged in resistance training, specifically the barbell back squat and bench press exercises, for at least one year, but were not actively participating in any competitive sport at a professional or amateur level. This categorization ensured participants had a foundational experience and skill set in the tested resistance exercises without being classified as competitive athletes. The sample size goal for reliability and validity analyses was calculated using a web-based ICC power analysis tool (36), showing that a sample of 36 comparisons would achieve a statistical power of 80%. In the current study, it is not each subject that counts but rather each comparison between the two devices (32). Therefore, because every repetition performed on the RepOne has an analogous repetition performed on the Tendo, each individual repetition is counted toward the sample for the following statistical analyses, for a total of 84 paired measurements (validity), and 42 individual measurements separately for the RepOne and Tendo (reliability). This was based on each subject performing three repetitions at seven loads for two exercises, repeated on two separate days. A sensitivity power analysis was conducted using G*Power statistical software (3.1.9.7) to estimate the smallest effect size that can be reliably detected for the SDC and SWC. To calculate the minimal effect size detectable with statistical significance, this power analysis considered each of the 14 participants providing 14 measurements per exercise and device, averaging both testing days to calculate SDC and SWC scores, culminating in a total effective sample size of 196 observations. The minimal effect size that this sample size is equipped to detect was determined at 0.20 across all intensities.

Each subject was informed of the experimental procedures and potential risks and benefits before signing an institutionally approved informed consent document prior to participate in the study. Prior to signing written consent, each subject completed a health and exercise status questionnaire (Physical Activity Readiness Questionnaire - PAR-Q), to screen for contraindications to exercise (e.g., heart disease, current or recent neuromuscular or musculoskeletal problems/injuries, serious musculoskeletal disorders, etc.). All sessions were supervised by a Certified Strength and Conditioning Specialist (CSCS) to ensure correct technique and adherence to the training protocol. Additional safety measures for all exercise testing included multiple spotters at all times, use of a power rack, and safety pins. Safety pins were individually set for each subject at the bottom of their squat and bench press positions to catch the barbell. Prior to the commencement of this investigation, the Institutional Review Board at Oklahoma State University approved this study (IRB # 21-189-STW), and the research conformed to the ethical guidelines set forth by the Helsinki Declaration for research with human subjects (41). This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (28).

Protocol
A randomized crossover repeated measures design was used to assess the reliability, validity, and sensitivity of the RepOne velocity variables (i.e., ACV and PCV) during the back squat and bench press. Subjects reported to the laboratory on 3 separate occasions, separated by at least 48 hours. During the first visit, subjects underwent 1RM testing for the back squat and bench press exercises in a randomized order with a 10-minute rest period allotted between exercises to precisely determine 1RM loads. The 1RM from each exercise was subsequently used in the 2 following visits. The tested device (i.e., RepOne) and reference device (Tendo Weightlifting Analyzer, Tendo Sports Machines, Trencin, Slovak Republic) were used concurrently to measure barbell velocity of each repetition during the 2nd and 3rd sessions.

During the first session, subjects were familiarized with all testing procedures and tested for 1RM strength in the back squat and bench press. Upon arrival at the laboratory, subjects' height and body mass were measured to the nearest 0.1 cm and 0.1 kg, respectively, using a portable stadiometer (Hopkins Road Rod #680214) and a digital scale (Adam Equipment CPWplus 150). Exercise order was randomly determined prior to the start of the warm-up. Briefly, subjects performed a five-minute self-selected warm-up prior to the start of 1RM testing. The 1RM testing was performed using standard 20 kg Olympic barbells and a free-weight bench. Loads for the warm-up sets were determined using the subjects' estimated 1RM (e1RM). Following a protocol previously reported by McBride et al. (24), warm-up sets consisted of 8–10 repetitions with 30% of e1RM, 4–6 repetitions with 50% of e1RM, 2–4 reps at 70% of e1RM, and 1 repetition with 90% of e1RM. A minimum of 3 minutes was allotted between sets to allow for sufficient recovery prior to their next attempt. Following the last warm-up set, the subject's true 1RM was determined as the heaviest load lifted through a full range of motion. Up to 4 attempts were permitted to establish a 1RM, and a minimum of 3-minute rest was allotted between each attempt. Subjects were given 10 minutes of rest upon completing 1RM testing for the first exercise. After 10 minutes, subjects repeated the 1RM protocol for the second exercise. During the bench press exercise, a repetition was considered successful if the subject lowered the bar to the chest, touched it briefly without bouncing, and then pressed upward until the arms were fully extended. For the back squat exercise, a repetition was considered successful if subjects lowered into a position so that the hip crease aligned with the top of the knee and then returned to a fully upright position with knees and hips extended.

To ensure consistency in the technique and set-up, subjects were instructed to unrack the empty barbell. Horizontal and vertical measurements were then taken in relation to the power rack and the units for each subject to ensure that the set-up was consistent between testing sessions. Tape was placed in front and behind subjects' feet as a marker during the squat for consistent foot placing during the walk-out and set-up. Tape was also placed around the barbell just outside the subject's pinky fingers to ensure consistent hand placement between sets and testing days. The velocity measuring devices were placed beside one another for all repetitions so that the lines of pull from the axis of both units were parallel. Additionally, the RepOne and Tendo line of pull positioning was measured from both horizontal and vertical distances relative to the power rack and each subject to ensure consistency across all testing days (Figure 1).

Participants reported to the laboratory on two separate occasions (sessions 2 and 3) for velocity testing that was separated from the familiarization and 1RM testing by a minimum of 48 hours. The exercise order during the two velocity testing sessions matched the order of the first laboratory visit. During each testing session, the subjects performed a 5-minute self-selected dynamic warm-up as they did during 1RM testing. Following the warm-up, the subjects then performed three repetitions of either bench press or back squat at relative loads (%1RM) ranging from 30-90% 1RM in ascending order. Due to the nature of the heavy loading, participants were asked to perform 1–3 repetitions at 90% 1RM. Load was increased in increments of 10% each set (i.e., 30%, 40%, etc.) with 3–5 minutes of rest allotted between sets to dissipate fatigue. Participants were instructed to perform each repetition as fast as possible during the concentric phase while controlling the eccentric phase of each rep. For both devices, the base of the sensor unit was placed directly beneath the barbell's trajectory in the vertical plane (this position is the natural unrack measurement recorded previously during the 1st visit). The Tendo device was placed directly on the floor and the RepOne unit was magnetically anchored to a weight plate resting on the floor. The cable of each unit was attached to the right side of the barbell at the end of the 'sleeve' using a magnet (RepOne) and Velcro strap (Tendo), respectively. ACV and PCV were recorded by both devices during each repetition and used for subsequent analysis. A minimum of 48 hours after session 2, the subjects returned to the laboratory and performed session 3 using identical testing procedures. ACV and PCV values were manually recorded from the Tendo via the unit's self-provided display unit (Weightlifting Analyzer V-207), and from the RepOne smartphone app (iOS 0.6.12) using an iPhone 12 pro max (iOS 15.3.1).

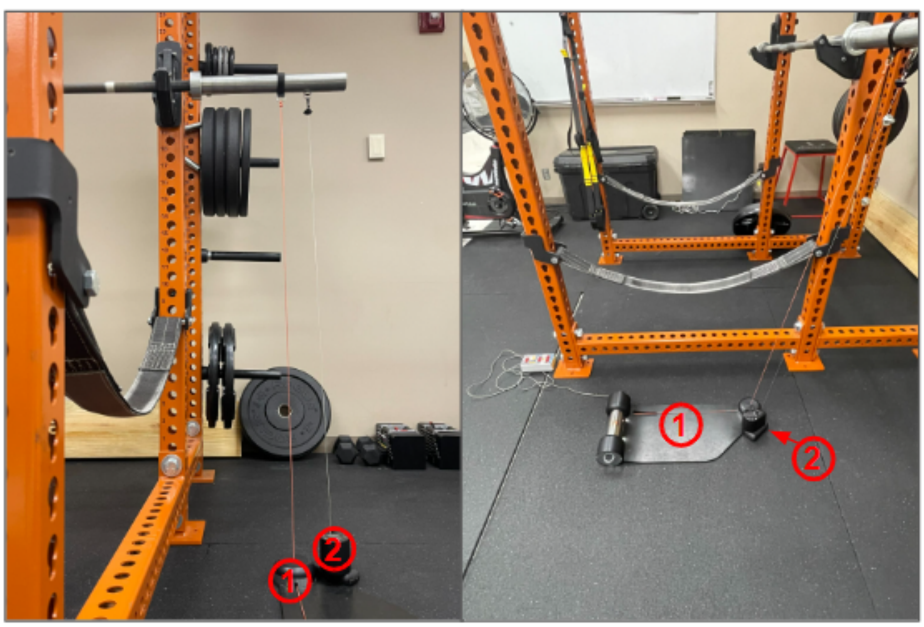

Figure 1. Linear position transducer (LPT) set-up. LPTs: 1 = Tendo, 2 = RepOne.

The Tendo sampling rate or frequency depends on the movement speed being measured. Specifically, when the speed is 2 m/s, the device operates at a sampling frequency of 200 Hz. This means it records 200 data points per second during the movement at this specific speed.

The RepOne has a theoretical maximum sampling rate of 50 KHz (data is being collected at a rate of 50,000 data points per second). The device uses a built-in timer peripheral on an Embedded Systems Programming (ESP) microcontroller called a Pulse Counter (PCNT), which has a resolution of 40 MHz. However, due to delays associated with deglitch filtering on the encoder's square waves and the resolution of the timer used to record incoming 'tics' from the encoder, the actual sampling frequency is reduced to 1 Mhz. Each reading represents approximately 0.875 millimeters (mm) of movement based on the encoder magnet used. The sampling rate allows the device to record instantaneous velocities of up to ~45 m/s, which is about an order of magnitude faster than any human movement. To summarize, the RepOne has a maximum sampling rate of 50 KHz using a high frequency silicon level hardware PCNT to detect every 0.875 mm of linear movement.

Statistical Analysis
Data were analyzed using IBM SPSS (v26, Armonk, New York) and alpha was set at a priori, $p < 0.05$. Back squat and bench press values (i.e., ACV and PCV) were measured and recorded across both testing days and are expressed as mean ± standard deviation (SD) (Table 2). Normality for each measure was determined via Shapiro-Wilk's tests, and visual box plots analysis was used to detect the presence of outliers. Concurrent validity of the RepOne device compared to the Tendo device was assessed with linear regression through the correlation coefficient (r), coefficient of determination (R^2), and the standard error of estimate (SEE) (Table 3). Strength of correlations was determined as low (0–0.30), moderate (0.31–0.49), strong (0.50–0.69), very strong (0.70–0.89), or near perfect (0.90–1) (8). ICCs with a two-way random model were calculated between each individual rep at the corresponding intensity for ACV and PCV between devices, to validate the RepOne against the Tendo (Table 4 and Table 5). Test-Retest reliability for the RepOne and Tendo was assessed using ICCs with a two-way random model calculated between testing days (Table 6 and Table 7). ICCs were classified using the following criteria: excellent (ICC = 0.91–1.00), good (ICC = 0.76–0.90), moderate (ICC = 0.51–0.75), and poor (ICC = 0.00–0.50) (19). Bland-Altman plots were used to evaluate the mean difference ('bias') with 95% confidence intervals, and limits of agreement (LOA) between both devices to identify any systemic differences, proportional bias, or potential outliers (Figures 2–5). Sensitivity analysis was performed by calculating the SDC from SEM for each individual at each load across both days and averaging the resulting SEM at each load for each lift and device (39). These averaged SEMs were multiplied by 1.96 and $\sqrt{2}$ to arrive at SDC (38). The SWC was calculated using the between-subject standard deviation multiplied by 0.2 to represent a small Cohen's d effect size (5, 7, 18). Cohen's d effect size was calculated to compare measurement error between the RepOne and Tendo units (Figures 6–7 and Table 8). Data used for this study are available on the Open Science Framework (https://osf.io/pxytn/).

RESULTS

Demographic information for all subjects is presented in Table 1. In total, 1122 samples were collected for RepOne PCV, 1127 samples for Tendo PCV, 1123 for RepOne ACV, and 1125 samples for Tendo ACV. Means and SD for both devices (i.e., Tendo and RepOne) and velocities (i.e., ACV and PCV) at each %1RM for both testing days can be found in Table 2. Linear regression results for total reps completed at each %1RM comparing RepOne and Tendo can be found in Table 3. Across both testing days, correlations were significant and very strong to near perfect during the back squat PCV (30–90%; r = 0.90–0.99, p < 0.01), back squat ACV (30–90%; r = 0.84–0.99, p < 0.01), bench press PCV (30–90%; r = 0.74–0.99, p < 0.01), and bench press ACV (30–90%; r = 0.81–0.99, p < 0.01).

Table 1. Participant characteristics for the whole group and each sex – mean (SD).

Measures	Males (n = 7)	Females (n = 7)
Age (years)	23.3 (1.7)	21.9 (1.6)
Height (cm)	179.0 (7.1)	166.8 (8.6)
Weight (kg)	92.4 (14.4)	67.9 (8.3)
Training Experience (years)	4.5 (1.9)	3.7 (2.3)
Back Squat 1RM (kg)	150.1 (14.4)	86.2 (21.2)
Bench Press 1RM (kg)	113.1 (16.2)	54.3 (17.5)

ICCs and 95% confidence intervals (CI) for validity and reliability analyses are presented in Tables 4–7. Outliers were removed during the analysis. Interrater values demonstrate good to excellent reliability between both devices (Tables 4 and 5). Intra-rater values ranged from moderate to excellent reliability indicating consistency of the RepOne device between testing days (Table 6), which was similarly observed to the intra-rater reliability for the Tendo (Table 7).

Table 2. Mean and standard deviations (SD) for peak concentric velocity (PCV) and average concentric velocity (ACV) for Tendo and RepOne at each relative load (%1RM) for Day 1 and Day 2 testing during the back squat and bench press exercises.

Tendo								
	Back Squat				Bench Press			
	Mean (SD)				Mean (SD)			
	PCV (m/s)		ACV (m/s)		PCV (m/s)		ACV (m/s)	
%1RM	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
30%	1.41 (0.21)	1.40 (0.23)	0.96 (0.12)	0.93 (0.19)	1.41 (0.24)	1.39 (0.25)	1.01 (0.18)	1.02 (0.18)
40%	1.34 (0.20)	1.32 (0.20)	0.91 (0.11)	0.90 (0.12)	1.23 (0.19)	1.21 (0.19)	0.93 (0.14)	0.91 (0.14)
50%	1.24 (0.17)	1.19 (0.21)	0.82 (0.10)	0.80 (0.11)	1.01 (0.15)	0.98 (0.16)	0.78 (0.11)	0.76 (0.12)
60%	1.15 (0.16)	1.11 (0.18)	0.73 (0.09)	0.72 (0.09)	0.84 (0.13)	0.82 (0.15)	0.66 (0.10)	0.64 (0.12)
70%	1.01 (0.16)	1.01 (0.18)	0.61 (0.08)	0.61 (0.09)	0.69 (0.11)	0.66 (0.13)	0.54 (0.09)	0.51 (0.10)
80%	0.90 (0.18)	0.91 (0.19)	0.49 (0.07)	0.50 (0.08)	0.54 (0.10)	0.51 (0.10)	0.39 (0.07)	0.37 (0.08)
90%	0.82 (0.16)	0.77 (0.20)	0.39 (0.08)	0.40 (0.08)	0.42 (0.08)	0.42 (0.11)	0.24 (0.06)	0.25 (0.07)
RepOne								
	Back Squat				Bench Press			
	Mean (SD)				Mean (SD)			
	PCV (m/s)		ACV (m/s)		PCV (m/s)		ACV (m/s)	
%1RM	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
30%	1.50 (0.24)	1.54 (0.33)	0.93 (0.15)	0.96 (0.14)	1.52 (0.26)	1.46 (0.30)	0.99 (0.18)	1.01 (0.20)
40%	1.45 (0.22)	1.44 (0.22)	0.90 (0.12)	0.89 (0.13)	1.33 (0.21)	1.29 (0.19)	0.92 (0.13)	0.89 (0.16)
50%	1.34 (0.20)	1.30 (0.24)	0.81 (0.11)	0.79 (0.11)	1.06 (0.18)	1.05 (0.16)	0.80 (0.15)	0.75 (0.12)
60%	1.25 (0.17)	1.20 (0.20)	0.70 (0.14)	0.70 (0.09)	0.90 (0.14)	0.88 (0.16)	0.66 (0.11)	0.63 (0.12)
70%	1.11 (0.17)	1.10 (0.20)	0.61 (0.09)	0.60 (0.09)	0.74 (0.12)	0.71 (0.14)	0.55 (0.10)	0.51 (0.10)
80%	0.98 (0.17)	0.99 (0.22)	0.49 (0.06)	0.50 (0.08)	0.58 (0.10)	0.56 (0.11)	0.38 (0.08)	0.37 (0.08)
90%	0.89 (0.18)	0.84 (0.22)	0.38 (0.14)	0.40 (0.09)	0.47 (0.11)	0.46 (0.11)	0.24 (0.07)	0.25 (0.07)

Table 3. RepOne vs. Tendo correlations (*r*), coefficient of determination (R^2), and standard error of estimate (SEE) for peak concentric velocity (PCV) and average concentric velocity (ACV) at each relative load (%1RM) for Day 1 and Day 2 testing during the back squat and bench press exercises.

Day 1												
	Back Squat						Bench Press					
	PCV			ACV			PCV			ACV		
%1RM	*r*	R^2	SEE	*r*	R^2	SEE	*r*	R^2	SEE	*r*	R^2	SEE
30%	0.90***	0.77	0.10	0.84***	0.70	0.07	0.99***	0.97	0.04	0.96***	0.93	0.05
40%	0.99***	0.99	0.02	0.97***	0.94	0.03	0.98***	0.97	0.03	0.96***	0.93	0.04
50%	0.99***	0.98	0.03	0.98***	0.96	0.02	0.88***	0.77	0.07	0.81***	0.66	0.07
60%	0.99***	0.99	0.01	0.99***	0.99	0.01	0.99***	0.99	0.02	0.97***	0.95	0.02
70%	0.98***	0.96	0.03	0.98***	0.97	0.02	0.98***	0.95	0.02	0.94***	0.88	0.03
80%	0.98***	0.96	0.03	0.99***	0.99	0.01	0.97***	0.95	0.02	0.98***	0.97	0.01
90%	0.98***	0.96	0.03	0.99***	0.99	0.01	0.74***	0.55	0.06	0.96***	0.91	0.02
Day 2												
	Back Squat						Bench Press					
	PCV			ACV			PCV			ACV		
%1RM	*r*	R^2	SEE	*r*	R^2	SEE	*r*	R^2	SEE	*r*	R^2	SEE
30%	0.96***	0.93	0.06	0.95***	0.90	0.15	0.93***	0.86	0.10	0.84***	0.71	0.10
40%	0.99***	0.99	0.01	0.96***	0.93	0.03	0.95***	0.9	0.06	0.90***	0.82	0.06
50%	0.99***	0.98	0.03	0.99***	0.98	0.02	0.97***	0.94	0.04	0.97***	0.93	0.03
60%	0.99***	0.99	0.01	0.95***	0.91	0.03	0.98***	0.96	0.03	0.99***	0.98	0.02
70%	0.99***	0.99	0.01	0.99***	0.99	0.01	0.99***	0.99	0.01	0.99***	0.97	0.02
80%	0.99***	0.99	0.02	0.99***	0.99	0.01	0.99***	0.98	0.01	0.99***	0.99	0.01
90%	0.99***	0.99	0.01	0.99***	0.98	0.01	0.98***	0.96	0.02	0.99***	0.97	0.01

* Indicates significance at $p \leq 0.05$; ** Indicates significance at $p \leq 0.01$; *** Indicates significance at $p \leq 0.001$.

Table 4. RepOne vs. Tendo intraclass correlation coefficients (ICCs) and 95% confidence intervals (95% CI) for peak concentric velocity (PCV) and average concentric velocity (ACV) at each relative load (%1RM) and repetition (Rep) for Day 1 and Day 2 testing during the back squat.

	Back Squat PCV ICC (95% CI)						Back Squat ACV ICC (95% CI)					
	Day 1			Day 2			Day 1			Day 2		
%1RM	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
30%	0.854 (0.545–0.953)***	0.994 (0.980–0.998)***	0.994 (0.982–0.998)***	0.935 (0.788–0.980)***	0.944 (0.816–0.983)***	0.993 (0.978–0.998)***	0.826 (0.458–0.944)**	0.974 (0.918–0.992)***	0.955 (0.860–0.986)***	0.993 (0.977–0.998)***	0.971 (0.906–0.991)***	0.946 (0.812–0.984)***
40%	0.996 (0.987–0.999)***	0.997 (0.991–0.999)***	0.995 (0.983–0.998)***	0.995 (0.984–0.999)***	0.995 (0.985–0.999)***	0.997 (0.989–0.999)***	0.994 (0.982–0.998)***	0.970 (0.907–0.990)***	0.989 (0.964–0.997)***	0.999 (0.997–1.000)***	0.996 (0.988–0.999)*	0.958 (0.863–0.987)***
50%	0.992 (0.975–0.997)***	0.994 (0.980–0.998)***	0.983 (0.948–0.995)***	0.995 (0.984–0.998)***	0.993 (0.976–0.998)***	0.990 (0.967–0.997)***	0.995 (0.984–0.998)***	0.995 (0.985–0.998)***	0.983 (0.946–0.994)***	0.989 (0.965–0.997)***	0.997 (0.990–0.999)*	0.995 (0.985–0.999)***
60%	0.997 (0.991–0.999)***	0.997 (0.991–0.999)***	0.995 (0.985–0.998)***	0.996 (0.985–0.999)***	0.997 (0.990–0.999)***	0.997 (0.989–0.999)***	0.994 (0.980–0.998)***	0.998 (0.993–0.999)***	0.996 (0.989–0.999)***	0.934 (0.784–0.980)***	0.990 (0.967–0.997)*	0.997 (0.991–0.999)***
70%	0.977 (0.928–0.993)***	0.997 (0.989–0.999)***	0.995 (0.985–0.998)***	0.997 (0.990–0.999)***	0.997 (0.990–0.999)***	0.996 (0.987–0.999)***	0.999 (0.996–1.000)***	0.997 (0.992–0.999)***	0.979 (0.936–0.993)***	0.999 (0.995–1.000)***	0.996 (0.988–0.999)*	0.998 (0.994–0.999)***
80%	0.968 (0.901–0.990)***	0.996 (0.989–0.999)***	0.994 (0.982–0.998)***	0.996 (0.988–0.999)***	0.997 (0.990–0.999)***	0.991 (0.972–0.997)***	0.993 (0.978–0.998)***	0.998 (0.994–0.999)***	0.997 (0.990–0.999)***	0.998 (0.995–1.000)***	0.998 (0.995–1.000)*	0.999 (0.997–1.000)***
90%	0.996 (0.989–0.999)***	0.993 (0.978–0.998)***	0.996 (0.985–0.999)***	0.997 (0.991–0.999)***	0.996 (0.986–0.999)***	0.997 (0.990–0.999)***	0.998 (0.994–0.999)***	0.999 (0.995–1.000)***	0.998 (0.995–1.000)***	0.980 (0.934–0.994)***	0.999 (0.997–1.000)*	0.999 (0.997–1.000)***

* Indicates significance at $p \leq 0.05$; ** Indicates significance at $p \leq 0.01$; *** Indicates significance at $p \leq 0.001$.

Table 5. RepOne vs. Tendo intraclass correlation coefficients (ICCs) and 95% confidence intervals (95% CI) for peak concentric velocity (PCV) and average concentric velocity (ACV) at each relative load (%1RM) and repetition (Rep) for Day 1 and Day 2 testing during the bench press exercises.

	Bench Press PCV						Bench Press ACV					
	ICC (95% CI)						ICC (95% CI)					
	Day 1			Day 2			Day 1			Day 2		
%1RM	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
30%	0.993 (0.979–0.998)***	0.991 (0.970–0.997)***	0.989 (0.965–0.996)***	0.961 (0.873–0.988)***	0.941 (0.805–0.982)***	0.944 (0.804–0.984)***	0.994 (0.980–0.998)***	0.966 (0.896–0.989)***	0.799 (0.341–0.939)***	0.899 (0.669–0.969)***	0.833 (0.451–0.949)**	0.991 (0.970–0.998)***
40%	0.989 (0.966–0.997)***	0.989 (0.966–0.996)***	0.990 (0.966–0.997)***	0.988 (0.960–0.996)***	0.938 (0.797–0.981)***	0.993 (0.976–0.998)***	0.993 (0.977–0.998)***	0.979 (0.934–0.993)***	0.967 (0.884–0.990)***	0.989 (0.965–0.997)***	0.987 (0.959–0.996)***	0.979 (0.921–0.994)***
50%	0.929 (0.778–0.977)***	0.935 (0.799–0.979)***	0.907 (0.711–0.970)***	0.988 (0.960–0.996)***	0.986 (0.954–0.996)***	0.979 (0.933–0.994)***	0.868 (0.589–0.958)***	0.881 (0.628–0.962)***	0.875 (0.610–0.960)***	0.990 (0.967–0.997)***	0.984 (0.947–0.995)***	0.976 (0.922–0.993)***
60%	0.998 (0.994–0.999)***	0.995 (0.985–0.998)***	0.988 (0.963–0.996)***	0.985 (0.951–0.995)***	0.994 (0.980–0.998)***	0.985 (0.951–0.995)***	0.982 (0.941–0.995)***	0.983 (0.944–0.995)***	0.986 (0.954–0.996)***	0.998 (0.995–0.999)***	0.986 (0.953–0.996)***	0.995 (0.984–0.999)***
70%	0.989 (0.965–0.996)***	0.978 (0.930–0.993)***	0.984 (0.947–0.995)***	0.995 (0.983–0.998)***	0.995 (0.984–0.998)***	0.998 (0.992–0.999)***	0.991 (0.972–0.997)***	0.944 (0.825–0.982)***	0.950 (0.843–0.984)***	0.988 (0.960–0.996)***	0.997 (0.989–0.999)***	0.990 (0.968–0.997)***
80%	0.995 (0.985–0.998)***	0.967 (0.897–0.989)***	0.994 (0.983–0.998)***	0.995 (0.983–0.998)***	0.991 (0.970–0.997)***	0.994 (0.981–0.998)***	0.993 (0.979–0.998)***	0.987 (0.960–0.996)***	0.989 (0.965–0.996)***	0.997 (0.989–0.999)***	0.992 (0.975–0.998)***	0.997 (0.992–0.999)***
90%	0.871 (0.598–0.959)***	0.986 (0.956–0.996)***	0.905 (0.689–0.971)***	0.989 (0.963–0.997)***	0.979 (0.927–0.994)***	0.996 (0.987–0.999)***	0.992 (0.976–0.998)***	0.945 (0.829–0.982)***	0.973 (0.911–0.992)***	0.990 (0.969–0.997)***	0.988 (0.959–0.997)***	0.996 (0.985–0.999)***

* Indicates significance at $p \leq 0.05$; ** Indicates significance at $p \leq 0.01$; *** Indicates significance at $p \leq 0.001$.

Table 6. RepOne intra-rater reliability between Day 1 and Day 2 testing: Intraclass correlation coefficients (ICCs) and 95% confidence intervals (95% CI) for peak concentric velocity (PCV) and average concentric velocity (ACV) at each relative load (%) and repetition (Rep) during the back squat and bench press exercises.

Back Squat (Day 1 vs. Day 2)						
	RepOne PCV			RepOne ACV		
	ICC (95% CI)			ICC (95% CI)		
%1RM	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
30%	0.890 (0.619–0.968)***	0.850 (0.508–0.954)***	0.862 (0.547–0.958)***	0.936 (0.792–0.981)***	0.785 (0.296–0.934)**	0.902 (0.680–0.970)***
40%	0.959 (0.866–0.988)***	0.882 (0.613–0.964)***	0.927 (0.746–0.979)***	0.957 (0.860–0.987)***	0.910 (0.706–0.973)***	0.909 (0.683–0.974)***
50%	0.874 (0.588–0.962)***	0.891 (0.643–0.967)***	0.849 (0.507–0.954)***	0.919 (0.735–0.975)***	0.928 (0.763–0.978)***	0.929 (0.768–0.978)***
60%	0.946 (0.823–0.983)***	0.901 (0.676–0.970)***	0.855 (0.525–0.956)***	0.857 (0.531–0.956)***	0.806 (0.364–0.941)**	0.911 (0.708–0.973)***
70%	0.942 (0.810–0.982)***	0.869 (0.569–0.960)***	0.900 (0.672–0.969)***	0.966 (0.888–0.990)***	0.875 (0.591–0.962)***	0.929 (0.767–0.978)***
80%	0.909 (0.700–0.972)***	0.930 (0.770–0.979)***	0.896 (0.660–0.968)***	0.892 (0.647–0.967)***	0.968 (0.894–0.990)***	0.905 (0.689–0.971)***
90%	0.883 (0.616–0.964)***	0.954 (0.839–0.987)***	0.958 (0.843–0.989)***	0.856 (0.528–0.956)***	0.925 (0.741–0.979)***	0.968 (0.881–0.991)***

Table 6. Continued.

	Bench Press (Day 1 vs. Day 2)					
	RepOne PCV			RepOne ACV		
	ICC (95% CI)			ICC (95% CI)		
%1RM	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
30%	0.914 (0.719–0.974)***	0.866 (0.561–0.959)***	0.926 (0.743–0.979)***	0.815 (0.393–0.944)**	0.766 (0.234–0.929)**	0.895 (0.637–0.970)***
40%	0.955 (0.851–0.986)***	0.882 (0.614–0.964)***	0.894 (0.633–0.970)***	0.935 (0.787–0.980)***	0.854 (0.523–0.956)***	0.908 (0.657–0.975)***
50%	0.787 (0.302–0.935)***	0.885 (0.623–0.965)***	0.931 (0.773–0.979)***	0.883 (0.617–0.964)***	0.768 (0.240–0.929)**	0.839 (0.472–0.951)**
60%	0.945 (0.821–0.983)***	0.880 (0.608–0.963)***	0.960 (0.868–0.988)***	0.970 (0.901–0.991)***	0.919 (0.734–0.975)***	0.911 (0.707–0.973)***
70%	0.878 (0.600–0.963)***	0.866 (0.561–0.959)***	0.925 (0.738–0.978)***	0.885 (0.625–0.965)***	0.810 (0.378–0.942)**	0.830 (0.444–0.948)**
80%	0.929 (0.767–0.978)***	0.915 (0.721–0.974)***	0.844 (0.488–0.952)***	0.955 (0.853–0.986)***	0.937 (0.793–0.981)**	0.785 (0.295–0.934)*
90%	0.786 (0.297–0.935)***	0.981 (0.928–0.995)***	0.763 (0.120–0.936)*	0.873 (0.585–0.961)***	0.868 (0.543–0.962)**	0.586 (−0.539–0.889)

* Indicates significance at $p \leq 0.05$; ** Indicates significance at $p \leq 0.01$; *** Indicates significance at $p \leq 0.001$.

Table 7. Tendo intra-rater reliability between Day 1 and Day 2 testing: Intraclass correlation coefficients (ICCs) and 95% confidence intervals (95% CI) for peak concentric velocity (PCV) and average concentric velocity (ACV) at each relative load (%1RM) and repetition (Rep) during the back squat and bench press exercises.

Back Squat (Day 1 vs. Day 2)						
	Tendo PCV			Tendo ACV		
%1RM	ICC (95% CI)			ICC (95% CI)		
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
30%	0.938 (0.796–0.981)***	0.885 (0.622–0.965)***	0.855 (0.524–0.956)***	0.948 (0.831–0.984)***	0.868 (0.568–0.960)***	0.897 (0.644–0.970)***
40%	0.952 (0.844–0.985)***	0.888 (0.632–0.966)***	0.942 (0.809–0.982)***	0.949 (0.834–0.985)***	0.944 (0.815–0.983)***	0.958 (0.863–0.987)***
50%	0.887 (0.630–0.966)***	0.905 (0.689–0.971)***	0.900 (0.672–0.969)***	0.928 (0.764–0.978)***	0.950 (0.837–0.985)***	0.931 (0.774–0.979)***
60%	0.949 (0.834–0.985)***	0.912 (0.712–0.973)***	0.867 (0.563–0.959)***	0.915 (0.720–0.974)***	0.835 (0.461–0.950)***	0.910 (0.706–0.973)***
70%	0.949 (0.832–0.984)***	0.890 (0.641–0.967)***	0.907 (0.696–0.972)***	0.971 (0.906–0.991)***	0.898 (0.665–0.969)***	0.917 (0.728–0.975)***
80%	0.893 (0.651–0.967)***	0.929 (0.767–0.978)***	0.903 (0.682–0.970)***	0.875 (0.592–0.962)***	0.966 (0.889–0.990)***	0.907 (0.694–0.971)***
90%	0.886 (0.626–0.965)***	0.953 (0.836–0.986)***	0.954 (0.827–0.987)***	0.866 (0.562–0.959)***	0.925 (0.739–0.978)***	0.970 (0.889–0.992)***

Table 7. Continued.

	Bench Press (Day 1 vs. Day 2)					
	Tendo PCV			Tendo ACV		
	ICC (95% CI)			ICC (95% CI)		
%1RM	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
30%	0.939 (0.801–0.981)***	0.934 (0.784–0.980)***	0.966 (0.882–0.990)***	0.926 (0.756–0.977)***	0.859 (0.537–0.957)***	0.809 (0.374–0.942)**
40%	0.970 (0.901–0.991)***	0.972 (0.908–0.991)***	0.928 (0.765–0.978)***	0.952 (0.843–0.985)***	0.935 (0.788–0.980)***	0.892 (0.647–0.967)***
50%	0.938 (0.796–0.981)***	0.886 (0.626–0.965)***	0.931 (0.773–0.979)***	0.939 (0.799–0.981)***	0.919 (0.733–0.975)***	0.907 (0.696–0.972)***
60%	0.954 (0.848–0.986)***	0.902 (0.680–0.970)***	0.975 (0.917–0.992)***	0.960 (0.861–0.988)***	0.901 (0.654–0.971)***	0.932 (0.765–0.981)***
70%	0.897 (0.663–0.969)***	0.845 (0.493–0.953)***	0.883 (0.593–0.966)***	0.913 (0.714–0.973)***	0.924 (0.752–0.977)***	0.900 (0.673–0.970)***
80%	0.913 (0.716–0.974)***	0.884 (0.621–0.965)***	0.910 (0.705–0.973)***	0.956 (0.857–0.987)***	0.924 (0.752–0.977)***	0.773 (0.256–0.931)**
90%	0.716 (0.068–0.913)*	0.925 (0.741–0.979)***	0.714 (−0.150–0.926)*	0.845 (0.492–0.953)***	0.877 (0.503–0.969)**	0.740 (−0.046–0.935)*

* Indicates significance at $p \leq 0.05$; ** Indicates significance at $p \leq 0.01$; *** Indicates significance at $p \leq 0.001$.

Bland-Altman plots are provided for 30-90% 1RM for both back squat and bench press ACV and PCV (Figures 2–5). The LOAs indicate where 95% of the differences between the two devices are expected. Inspection of plots and the line of best fit suggest greater random error and proportional bias for PCV than ACV during the back squat and bench press when comparing RepOne to Tendo. The mean difference between devices for the PCV indicated that the RepOne recorded higher PCV versus the Tendo across each exercise intensity (bench press = 0.039–0.107 m/s; back squat = 0.072–0.110 m/s). Furthermore, a positive correlation was observed for PCV at 30% (back squat, r = 0.29; bench press, r = 0.36), 40% (back squat, r = 0.62; bench press, r = 0.40), 50% (back squat, r = 0.59; bench press, r = 0.34), 60% (back squat, r = 0.69; bench press, r = 0.54), 70% (back squat, r = 0.34; bench press, r = 0.39), 80% (back squat, r = 0.45; bench press, r = 0.18), and 90% (back squat, r = 0.70; bench press, r = 0.21), indicating a proportional bias for the RepOne. The RepOne measured a lower mean difference for ACV values during the back squat relative to the Tendo across all intensities (−0.029–−0.002 m/s). Positive relationships were observed for 30% (r = 0.33), 40% (r = 0.28), 50% (r = 0.12), 60% (r = 0.26), and 70% (r = −.22) indicating proportional bias in the RepOne; however, negative relationships were observed at the higher intensities of 80% (r = −0.28) and 90% (r = −0.20) indicating proportional bias in the Tendo. The mean difference in ACV for the bench press ranged from −0.022–0.015 m/s. Low negative correlations were observed for lower intensities of 30% (r = −0.05) and 40% (r = −0.12), indicating almost negligible inverse relationships between the compared measurements. Conversely, low-to-strong positive relationships were observed for 50% (r = 0.53), 60% (r = 0.44), 70% (r = 0.36), 80% (r = 0.28), and 90% (r = 0.42). The trend in positive relationships observed across most intensities for both exercises and velocity metrics (i.e., ACV and PCV) may suggest that the likelihood of observing larger differences between the two devices increases, pointing towards a tendency in proportional bias across intensities at faster velocities for the RepOne compared to the Tendo.

Sensitivity analysis for all conditions, loads, and devices is presented in Table 8 and Figures 6–7. The SDC for the RepOne device ranged from 0.113 to 0.274 m/s (M = 0.161, SD = 0.061) for bench press ACV, from 0.123–0.298 m/s (M = 0.194, SD = 0.074) for bench press PCV, from 0.075 −0.183 m/s (M = 0.12, SD = 0.044) for back squat ACV, and from 0.15–0.288 m/s (M = 0.21, SD = 0.067) for back squat PCV. For the Tendo device, SDC ranged from 0.102–0.169 m/s (M = 0.128, SD = 0.024) for bench press AVC, from 0.114–0.199 m/s (M = 0.152, SD = 0.037) for bench press PVC, from 0.077–0.171 m/s (M = 0.107, SD = 0.039) for back squat AVC, and from 0.132–0.258 m/s (M = 0.163, SD = 0.047) for back squat PVC. The SDC of the RepOne device was greater than the Tendo unit for all loads except for 60% and 90% in bench press ACV; 70% in bench press PCV; and 30%, 70%, and 80% in back squat ACV.

The SWC for the RepOne device ranged from 0.014–0.038 m/s (M = 0.024, SD = 0.008) for bench press ACV, from 0.022–0.056 m/s (M = 0.033, SD = 0.012) for bench press PCV, from 0.015–0.028 m/s (M = 0.02, SD = 0.005) for back squat ACV, and from 0.037–0.056 m/s (M = 0.042, SD = 0.007) for back squat PCV. For the Tendo device, SDC ranged from 0.014–0.036 m/s (M = 0.022, SD = 0.007) for bench press AVC, from 0.019–0.048 m/s (M = 0.03, SD = 0.01) for bench press PVC, from 0.015–0.032 m/s (M = 0.021, SD = 0.006) for back squat AVC, and from 0.033–0.043 m/s (M = 0.037, SD = 0.003) for back squat PVC. The SWC of the RepOne device was greater than the Tendo unit for all loads except for 30%, 50%, 60%, and 80% loads in the back squat ACV.

Across the back squat and bench press, the Tendo unit had smaller within-subject error than the RepOne unit in nine of 14 loads for ACV, and in 13 of 14 loads for PCV. Across the back squat and bench press, the Tendo unit had smaller between-subject error than the RepOne unit in four of 14 loads for ACV, and in 14 of 14 loads for PCV. The RepOne device's SDC averaged across loads and exercises was 0.141 m/s for ACV and 0.202 m/s PCV, and for the Tendo device they were 0.117 m/s for ACV and 0.157 m/s for PCV. The RepOne device's SWC averaged across loads and exercises was 0.022 m/s for ACV and 0.038 m/s PCV, and for the Tendo device, they were 0.022 m/s for ACV and 0.033 m/s for PCV.

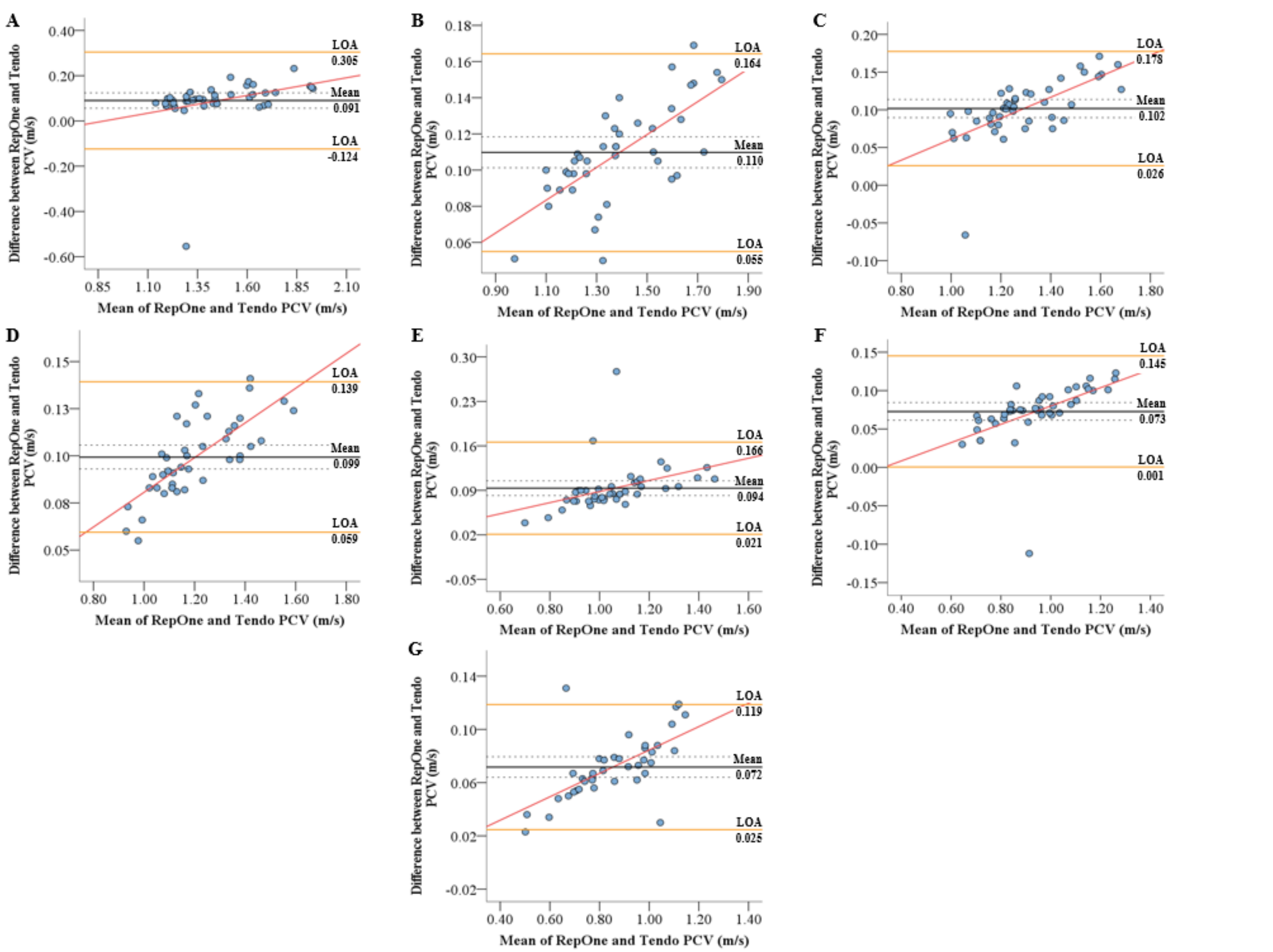

Figure 2. Bland–Altman plots showing variation of the RepOne compared to the Tendo for peak concentric velocity during the Back Squat performed with loads of 30 (**A**), 40 (**B**), 50 (**C**), 60 (**D**), 70 (**E**), 80 (**F**), and 90% (**G**) of participants' 1RM Back Squat. The black line displays the mean difference, the dotted lines represent the 95% confidence intervals, the orange lines represent the upper and lower levels of agreement, and the red line represents the line of best fit. Mean = mean difference; LOA = levels of agreement; PCV = peak concentric velocity.

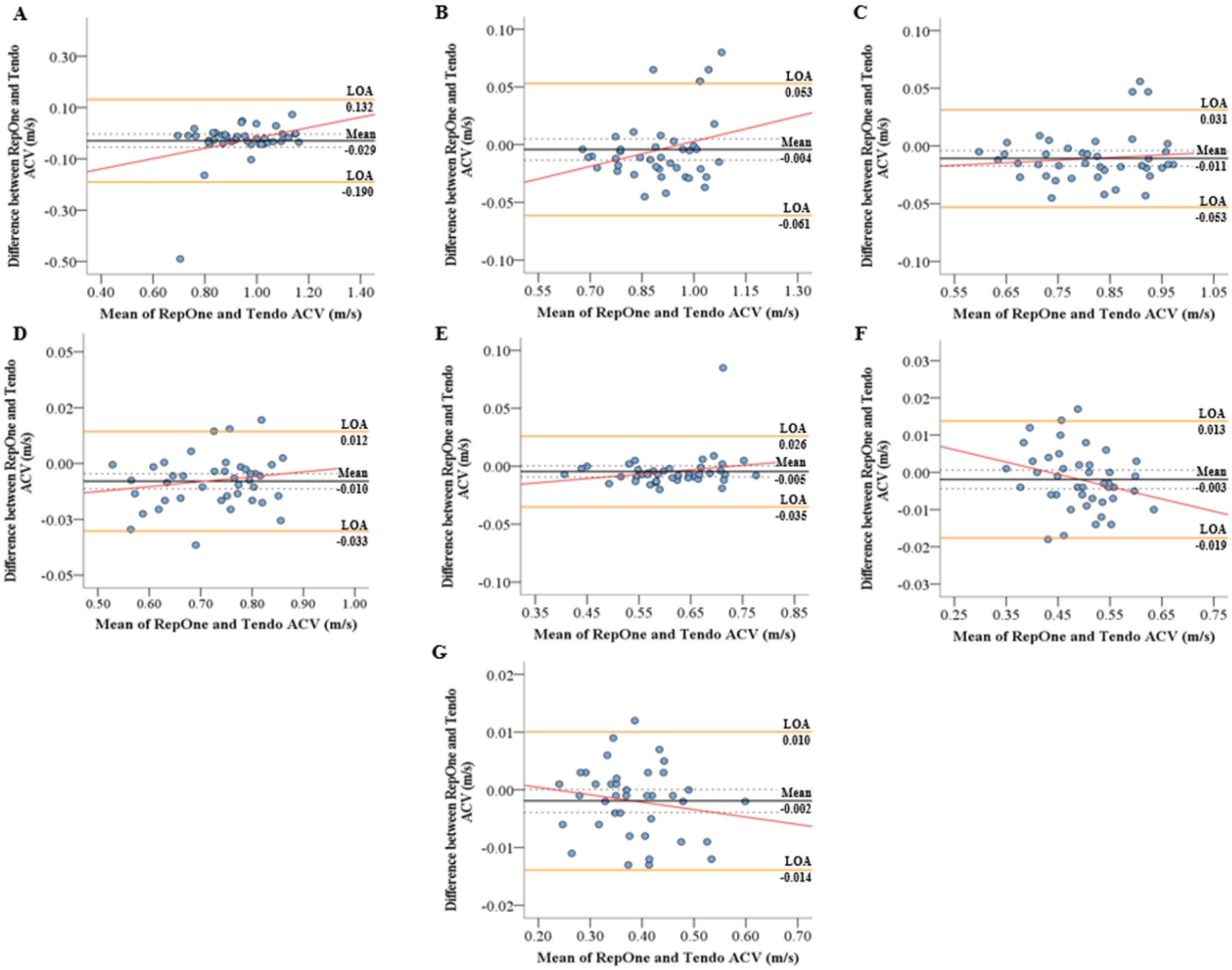

Figure 3. Bland–Altman plots showing variation of the RepOne compared to the Tendo for average concentric velocity during the Back Squat performed with loads of 30 (**A**), 40 (**B**), 50 (**C**), 60 (**D**), 70 (**E**), 80 (**F**), and 90% (**G**) of participants' 1RM Back Squat. The black line displays the mean difference, the dotted lines represent the 95% confidence intervals, the orange lines represent the upper and lower levels of agreement, and the red line represents the line of best fit. Mean = mean difference; LOA = levels of agreement; ACV = average concentric velocity.

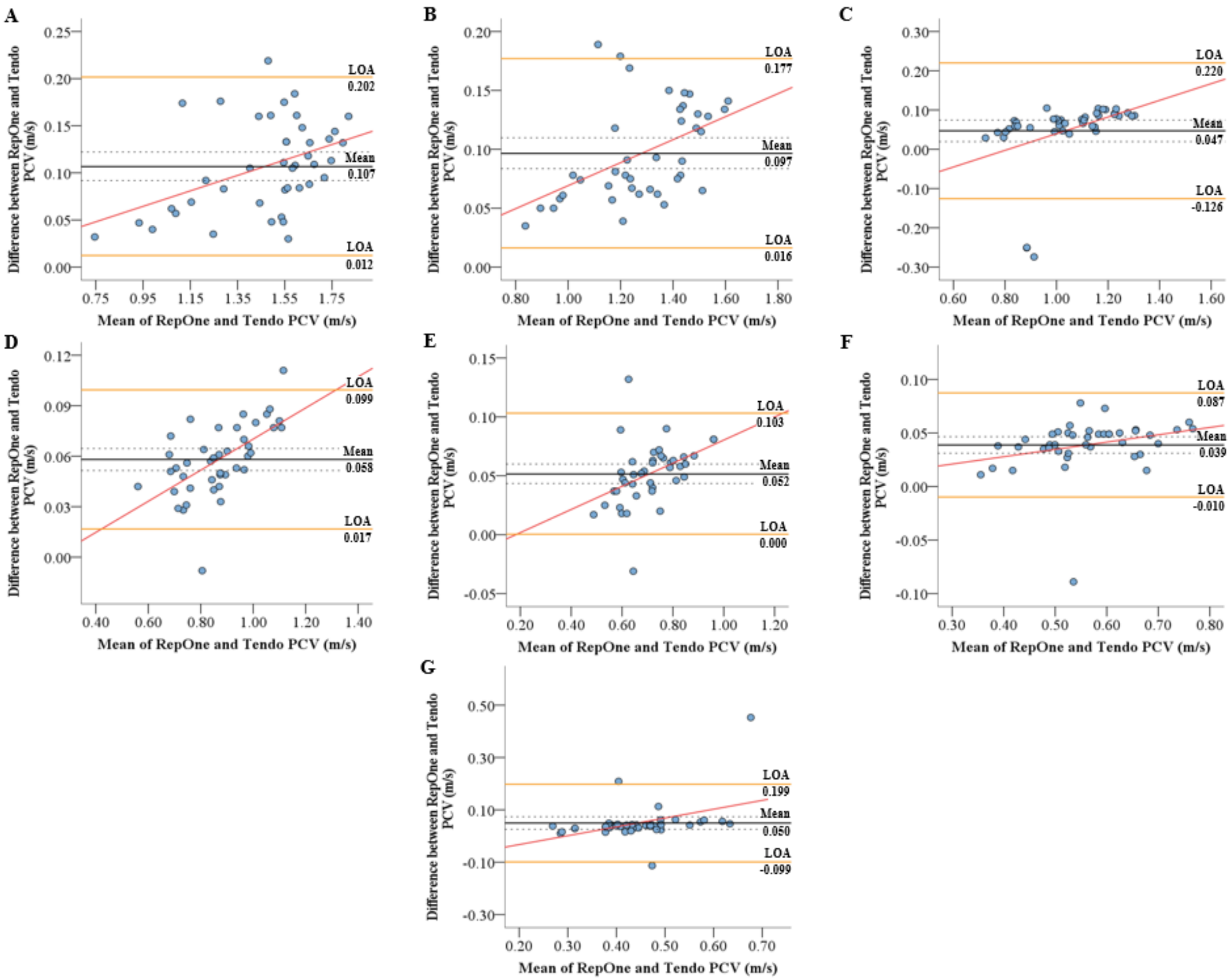

Figure 4. Bland–Altman plots showing variation of the RepOne compared to the Tendo for peak concentric velocity during the Bench Press performed with loads of 30 (**A**), 40 (**B**), 50 (**C**), 60 (**D**), 70 (**E**), 80 (**F**), and 90% (**G**) of participants' 1RM Bench Press. The black line displays the mean difference, the dotted lines represent the 95% confidence intervals, the orange lines represent the upper and lower levels of agreement, and the red line represents the line of best fit. Mean = mean difference; LOA = levels of agreement; PCV = peak concentric velocity.

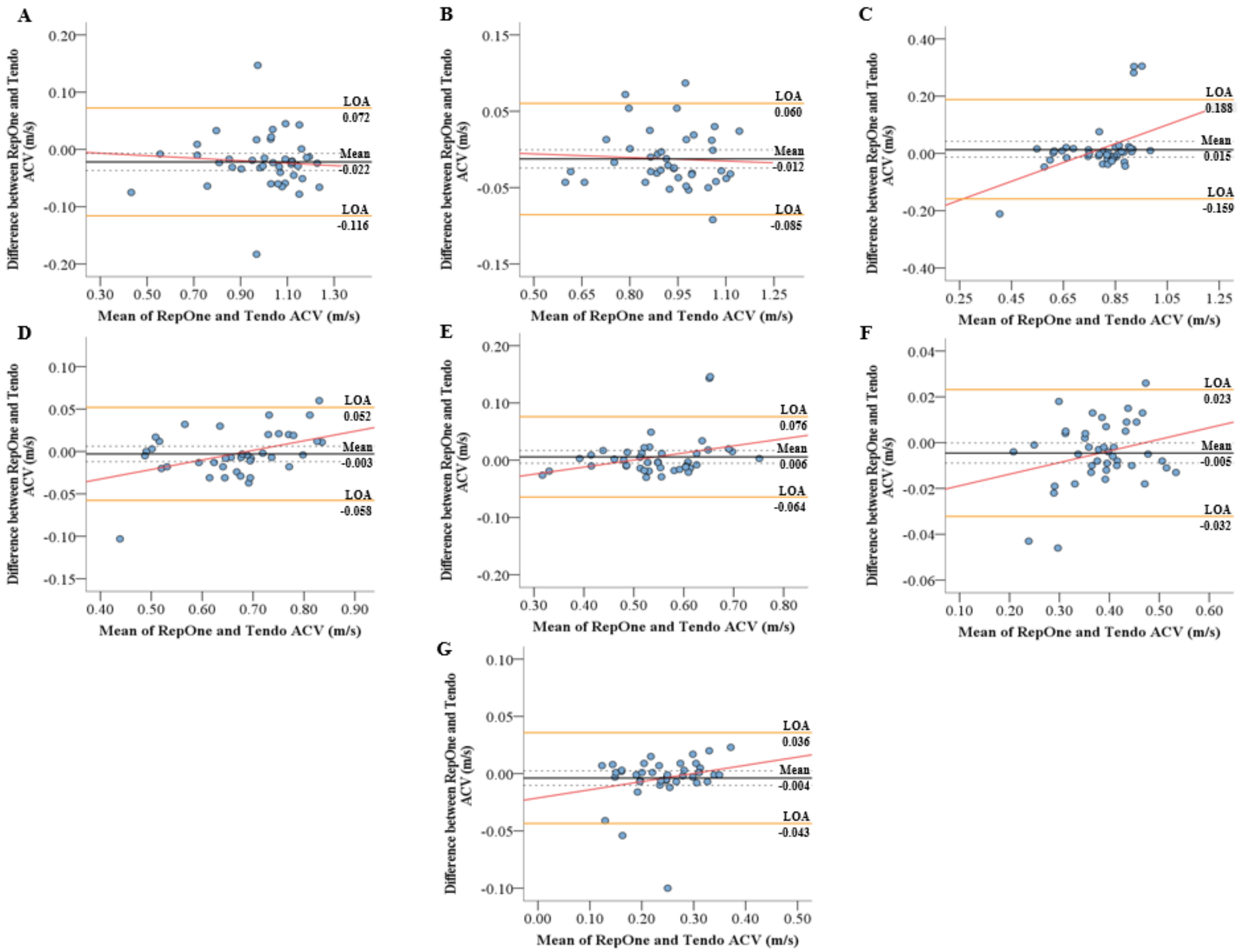

Figure 5. Bland–Altman plots showing variation of the RepOne compared to the Tendo for average concentric velocity during the Bench Press performed with loads of 30 (**A**), 40 (**B**), 50 (**C**), 60 (**D**), 70 (**E**), 80 (**F**), and 90% (**G**) of participants' 1RM Bench Press. The black line displays the mean difference, the dotted lines represent the 95% confidence intervals, the orange lines represent the upper and lower levels of agreement, and the red line represents the line of best fit. Mean = mean difference; LOA = levels of agreement; ACV = average concentric velocity.

Table 8. RepOne and Tendo smallest detectable change (SDC) and smallest worthwhile change (SWC) for average concentric velocity (ACV) and peak concentric velocity (PCV) at each relative load (%1RM) during the bench press and back squat exercises.

Bench Press								
	RepOne ACV (m/s)		RepOne PCV (m/s)		Tendo ACV (m/s)		Tendo PCV (m/s)	
%1RM	SDC	SWC	SDC	SWC	SDC	SWC	SDC	SWC
90%	0.136	0.014	0.221**	0.023*	0.144	0.014	0.185**	0.019*
80%	0.115	0.016	0.123	0.022	0.107	0.016	0.114	0.02
70%	0.133*	0.021*	0.146***	0.026	0.113*	0.019*	0.199***	0.024
60%	0.113*	0.024	0.14*	0.03*	0.136*	0.023	0.127*	0.028*
50%	0.136**	0.028**	0.145**	0.035*	0.102**	0.023**	0.115**	0.031*
40%	0.22***	0.03*	0.285***	0.04*	0.126***	0.027*	0.134***	0.037*
30%	0.274***	0.038*	0.298***	0.056**	0.169***	0.036*	0.187***	0.048**
Average	0.161**	0.024*	0.194**	0.033*	0.128**	0.022*	0.152**	0.03*

Back Squat								
	RepOne ACV (m/s)		RepOne PCV (m/s)		Tendo ACV (m/s)		Tendo PCV (m/s)	
%1RM	SDC	SWC	SDC	SWC	SDC	SWC	SDC	SWC
90%	0.157	0.017	0.284*	0.04**	0.153	0.016	0.258*	0.036**
80%	0.085	0.015	0.161*	0.039***	0.089	0.015	0.136*	0.035***
70%	0.075	0.018	0.155*	0.038**	0.077	0.017	0.133*	0.034**
60%	0.096	0.018	0.15*	0.037**	0.09	0.018	0.132*	0.033**
50%	0.09	0.021	0.161*	0.042***	0.082	0.021	0.146*	0.038***
40%	0.183***	0.024*	0.288***	0.043***	0.082***	0.023*	0.146***	0.039***
30%	0.156*	0.028***	0.27***	0.056***	0.171*	0.032***	0.191***	0.043***
Average	0.12*	0.02	0.21***	0.042***	0.107*	0.021	0.163***	0.037***

* Indicates Cohen's $d \geq 0.2$, ** indicates Cohen's $d \geq 0.5$, *** indicates Cohen's $d \geq 0.8$.

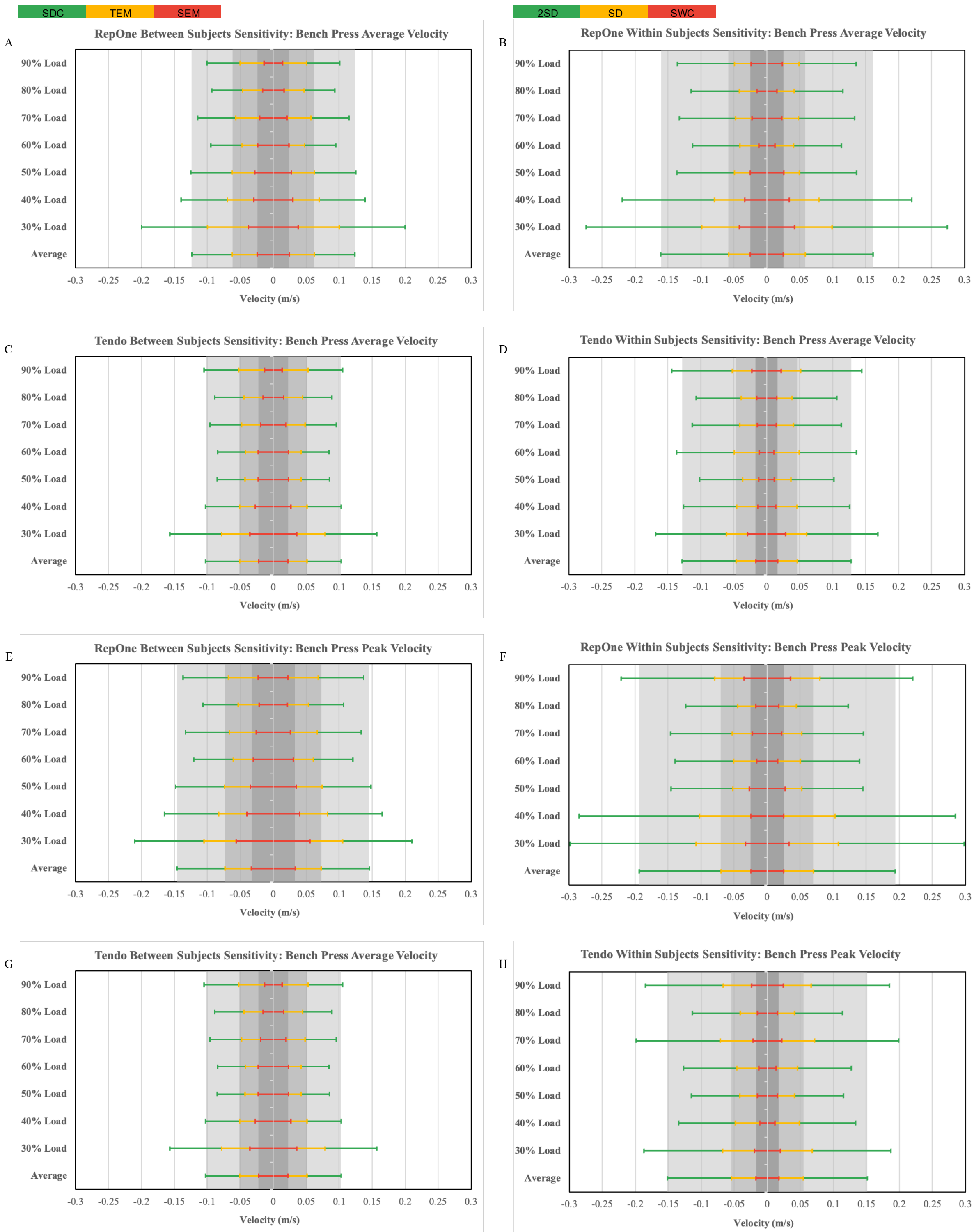

Figure 6. Comparison of various measures of within- and between-subjects reliability across percent loads of participants' 1RM Bench Press. The shaded areas represent the average across all loads. Between-subjects measures: SEM = standard error of the measurement; TEM = technical error of the measurement; SDC = smallest detectable change. Within-subjects measures: SWC = smallest worthwhile change; SD = standard deviation; 2SD = 2 · standard deviation.

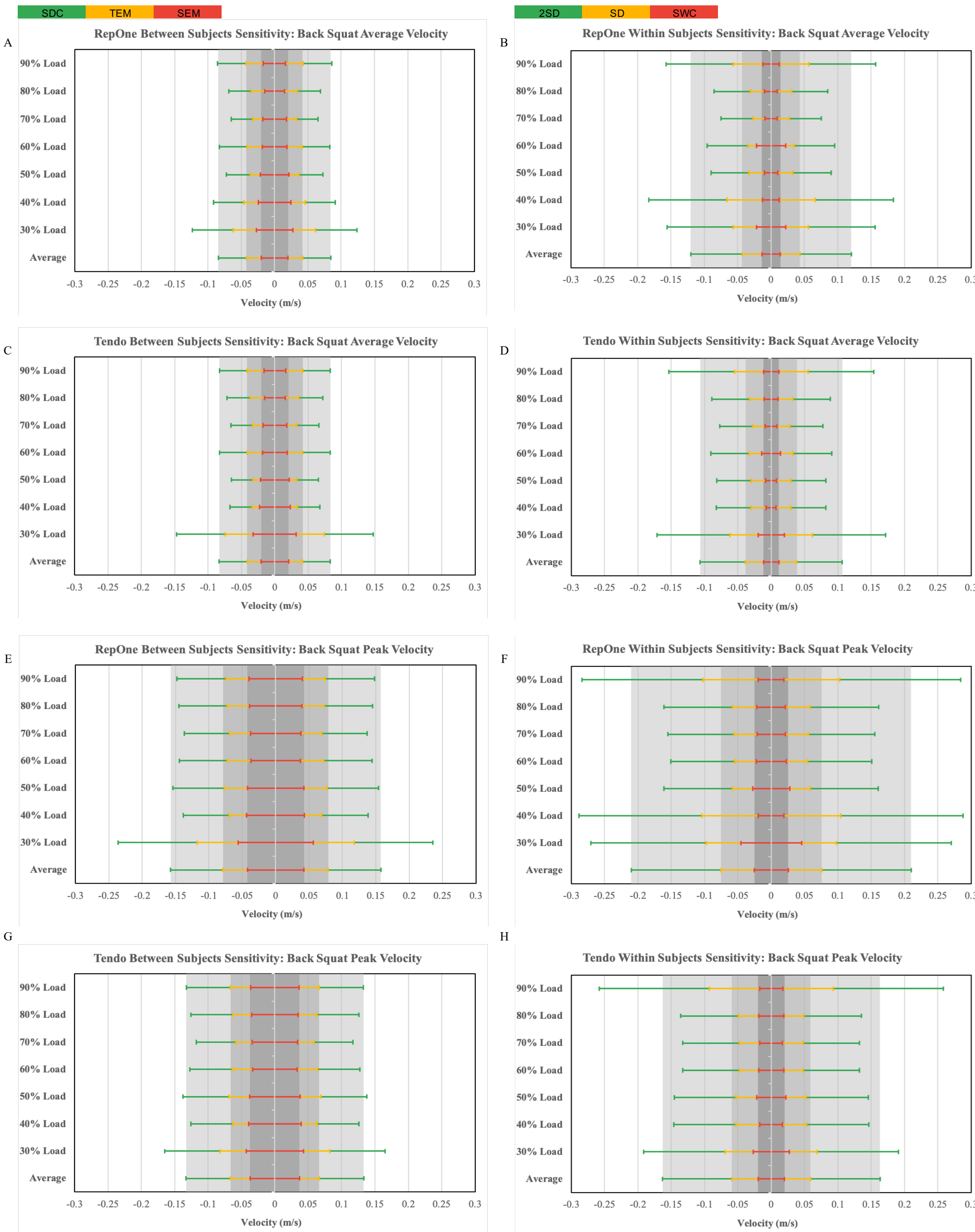

Figure 7. Comparison of various measures of within- and between-subjects reliability across percent loads of participants' 1RM Back Squat. The shaded areas represent the average across all loads. Between-subjects measures: SEM = standard error of the measurement; TEM = technical error of the measurement; SDC = smallest detectable change. Within-subjects measures: SWC = smallest worthwhile change; SD = standard deviation; 2SD = 2 · standard deviation.

DISCUSSION

The goal of this study was to investigate the reliability, validity, and sensitivity of a new LPT device (i.e., RepOne) used to assess ACV and PCV during back squat and bench press. The overall results demonstrate good to excellent reliability between testing days for the RepOne device suggesting the RepOne device can be a viable option when implemented into a continual training and monitoring protocol. Variations in measurements between testing days were minor and can likely be attributed to fluctuations in subject performance rather than errors in the device.

The RepOne demonstrated a strong relationship with the Tendo regarding ACV and PCV values, with the ability of RepOne to accurately estimate the recorded velocity metrics for the Tendo across various intensities and during all sessions was notable (Table 3). Additional validation steps were taken as recommended by Dixon et al. (10). This validation sequence resulted in an interesting and perhaps practically useful finding. A closer examination of the validity between the devices from ICCs between each individual rep across all intensities of the back squat and bench press for both days suggests strong agreement in PCV and ACV. Results from the Bland-Altman plots indicate that the RepOne generally resulted in higher values than the Tendo for the PCV, but lower ACV values for both exercises across intensities. It's unlikely that these differences are meaningful regarding ACV, as the RepOne, on average, measured −0.029–−0.002 m/s lower during the back squat, while the mean differences between both devices ranged from −0.022–−0.015 m/s lower during the bench press. These differences were lower than the SDC for back squat and bench press at all loads in both devices. The PCV, however, measured consistently higher from the RepOne, with back squat ranging from 0.07–0.10 m/s and bench press ranging from 0.05–0.11 m/s. The greater differences observed in PCV between devices may be attributed to variance in sensitivity between devices for capturing PCV during the back squat and bench press.

The Bland-Altman plot interpretation for comparing RepOne and Tendo devices reveals practical insights and considerations into the measurement differences across various exercise intensities. The observed mean differences and the tendency for positive proportional bias between the devices could reflect the RepOne devices' higher sampling frequency (50 KHz) compared to Tendo's (200 Hz when the speed is 2 m/s). This discrepancy suggests that RepOne may offer more detailed data capture, particularly at faster velocities typical of lifting across a wide range of intensities during strength training (21, 22). However, this wasn't inherently observed for ACV during the back squat at 80% and 90% 1RM, or during the bench press at 30% and 40% 1RM. Furthermore, inspection of the plots indicated that RepOne consistently recorded higher PCV values than Tendo across all exercise intensities for both back squat and bench press exercises. This discrepancy, as evidenced by positive correlations for PCV, suggests a proportional bias towards the RepOne, indicating that as the PCV values increase within each intensity, the magnitude of the difference between the devices also increases. In contrast, for ACV, RepOne had a tendency to record lower mean differences than Tendo, with a mix of positive and negative relationships observed across different intensities.

The varying relationships at different intensities highlight the potential differences in data capture between both devices depending on the velocity metric, intensity, and exercise tested. Additionally, greater mean differences and proportional bias observed for PCV compared to ACV suggest that the precision and agreement between these devices vary notably between different types of velocity measurements. The RepOne's higher sampling rate may provide an advantage in capturing more accurate data at faster velocities, which could explain its tendency towards higher readings and the observed proportional bias. However, the observed difference appears to diminish as the intensity increases, particularly when measuring ACV, indicating a complex interaction between both device measurement capabilities and exercise velocity measurements at specific intensities. Consequently, determining which LPT device (i.e., RepOne or Tendo) offers the most accurate PCV and ACV measurements remains inconclusive within this study's scope, as comparisons were made solely between these two devices without validation against an independent, gold-standard assessment like 3D motion capture technology (15). Furthermore, the ICCs suggest a high level of inter-rater reliability, indicating that both devices consistently provided similar velocity readings across various repetitions, intensities, and on different days for the back squat and bench press exercises. Collectively, while there may be differences in the data captured between devices, the overall validity and reliability between RepOne and Tendo in recording similar velocity measurements (i.e., PCV and ACV) remains comparably high across different intensities and exercises.

Sensitivity analysis revealed within- and between-subject sensitivity for both devices to be within tolerable limits for the practitioner when compared to both commonly established velocity targets and velocity-loss thresholds. For example, early work by Mann and colleagues (21, 22) established five mean velocity-based intensity zones that more-or-less persist to this day, ranging from < 0.50 m/s for absolute strength, 0.50–0.75 m/s for accelerative strength, 0.75–1.00 m/s for strength-speed, 1.00–1.30 m/s for speed strength, and > 1.3 m/s for starting strength. These so-called velocity zones range from 0.25 to 0.30 m/s in magnitude, and in the current analysis, the SDC and SWC of both devices are less than this range. Research investigating more granular changes in intensity has noted that an increase or decrease of 5% of 1RM in the bench press exercise results in roughly a 0.07–0.09 m/s change in ACV (16). Although the present data reveal an average SDC larger than this for each device in the bench press (RepOne = 0.161 m/s, Tendo = 0.128 m/s), the SWC was well within this range (RepOne = 0.024 m/s, Tendo = 0.022 m/s). An important finding from our study revealed that the RepOne device generally exhibited higher SDC and SWC values compared to the Tendo, except for specific loads in certain conditions, which could be due to the higher sampling frequency of the RepOne (26).

That said, the arbitrary use of a small effect size of 0.2 for the calculation of SWC in sport science should be called into question when applied to VBT training, given that in this case the SWC was less than the within- and between-subject error at every load for both devices on both the SQ and bench press. To put it in terms of equivalent load, the SWC across both exercises and devices ranged from 0.014 to 0.056 m/s, which may be equivalent to between 1 to 4% of 1RM based on González-Badillo & Sánchez-Medina's data (16) that found 5% loading changes resulted in 0.07 to 0.09 m/s changes in velocity.

The current results do not support the use of single arbitrary thresholds to distinguish between true change and measurement error, as the observed estimates of error were altered not only by device, but also by exercise type and percent load. These findings point to the importance of considering additional measures of error such the SEM, TEM, or SDC to generate a band of uncertainty, outside of which true change is more likely to have occurred. Furthermore, practitioners are encouraged to consider that these error bands may expand or contract depending on the load, with the current investigation showing more variability at loads below 50% and above 80%, which has been noted previously (6, 17). Another approach would be to group loads into slow, medium, and high velocities and calculate device sensitivity within those groups (16).

The visual inspection of the sensitivity plots revealed that the loads with the highest variability tended to be 30%, 40%, regardless of exercise or device. This could be due to a number of factors. Although the subjects were recreationally trained, they may not have had prior experience with VBT or been previously coached to perform all repetitions with maximal movement intent. This unfamiliarity could result in greater rep-to-rep variability at lighter loads because the subjects were not accustomed to providing maximal force during such submaximal efforts.

Several limitations in this research should be acknowledged. The current study only examined ACV and PCV during the back squat and bench press in 10% increments starting at 30% of 1RM up to 90% 1RM, thus a possible limitation is the extrapolation of these findings to other exercises and intensities. The exercises used in this study were conducted as a free-weight setting and were not performed in a Smith machine. Nonetheless, the stability across intensities in a free-weight setting is proof of the ecological validity of the RepOne. The back squat and bench press were chosen as they are common exercises that are indicative of both lower and upper body strength, which likely has a large carryover to many movements. Thus, the accuracy of these LPT's should be assessed during other multi-joint exercises, especially weightlifting movements. In conclusion, the results of this study suggest that for best standardization of testing and monitoring practices these devices should not be used interchangeably for PCV, but the RepOne provides comparable ACV values as a TENDO.

The RepOne device provides reliable measurements across multiple testing days through a wide range of intensities and velocities. Importantly, testing was done using the free-weight back squat and bench press exercises. The PCV values tended to be higher than what was provided on the TENDO, however, ACV values were slightly lower from the RepOne. The differences in ACV are likely not meaningful when considering the implementation of the RepOne into daily training, but caution may be warranted when attempting to compare ACV and PCV values between devices. For best practice, the authors suggest not using these devices interchangeably. If switching from one device to another, it's recommended to retest athletes or clients if loading parameters are referenced from a load-velocity profile using a specific device or when interpreting data to determine athlete readiness. Furthermore, practitioners are encouraged to conduct in-house calculations of measurement error using SEM or SDC, and caution is warranted when interpreting relatively small velocity changes at very heavy (> 80%) or very light (< 50%) loads.

ACKNOWLEDGEMENTS

The authors would like to thank the subjects for their participation in this study and for RepOne Strength supplying the Tactical Fitness & Nutrition Lab with their device used in this study.

REFERENCES

1. Abbott JC, Wagle JP, Sato K, Painter K, Light TJ, Stone MH. Validation of inertial sensor to measure barbell kinematics across a spectrum of loading conditions. Sports 8(7): 93, 2020.

2. Balsalobre-Fernández C, Kuzdub M, Poveda-Ortiz P, Campo-Vecino JD. Validity and reliability of the PUSH wearable device to measure movement velocity during the back squat exercise. J Strength Cond Res 30(7): 1968-1974, 2016.

3. Banyard HG, Nosaka K, Haff GG. Reliability and validity of the load–velocity relationship to predict the 1RM back squat. J Strength Cond Res 31(7): 1897-1904, 2017.

4. Banyard HG, Nosaka K, Sato K, Haff GG. Validity of various methods for determining velocity, force, and power in the back squat. Int J Sports Physiol Perform 12(9): 1170-1176, 2017.

5. Buchheit M. Magnitudes matter more than beetroot juice. Sport Perform Sci Rep 15: 1-3, 2018.

6. Carroll KM, Sato K, Bazyler CD, Triplett NT, Stone MH. Increases in variation of barbell kinematics are observed with increasing intensity in a graded back squat test. Sports 5(3): 51, 2017.

7. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates; 1988.

8. Cohen P, West SG, Aiken LS. Applied multiple regression/correlation analysis for the behavioral sciences. 3rd ed. Mahwah, NJ: Lawrence Erlbaum Associates; 2003.

9. Courel-Ibáñez J, Martínez-Cava A, Morán-Navarro R, Escribano-Peñas P, Chavarren-Cabrero J, González-Badillo JJ, Pallarés JG. Reproducibility and repeatability of five different technologies for bar velocity measurement in resistance training. Ann Biomed Eng 47(7): 1523-1538, 2019.

10. Dixon PM, Saint-Maurice PF, Kim Y, Hibbing P, Bai Y, Welk GJ. A primer on the use of equivalence testing for evaluating measurement agreement. Med Sci Sports Exerc 50(4): 837, 2018.

11. Dorrell HF, Moore JM, Smith MF, Gee TI. Validity and reliability of a linear positional transducer across commonly practised resistance training exercises. J Sports Sci 37(1): 67-73, 2019.

12. Dorrell HF, Smith MF, Gee TI. Comparison of velocity-based and traditional percentage-based loading methods on maximal strength and power adaptations. J Strength Cond Res 34(1): 46-53, 2020.

13. García-Ramos A, Pestaña-Melero FL, Pérez-Castilla A, Rojas FJ, Haff GG. Mean velocity vs. mean propulsive velocity vs. peak velocity: Which variable determines bench press relative load with higher reliability? J Strength Cond Res 32(5): 1273-1279, 2018.

14. Garnacho-Castaño MV, López-Lastra S, Maté-Muñoz JL. Reliability and validity assessment of a linear position transducer. J Sports Sci Med 14(1): 128, 2015.

15. Goldsmith JA, Trepeck C, Halle JL, Mendez KM, Klemp A, Cooke DM, Haischer MH, Byrnes RK, Zoeller RF, Whitehurst M. Validity of the open barbell and tendo weightlifting analyzer systems versus the Optotrak Certus 3D motion-capture system for barbell velocity. Int J Sports Physiol Perform 14(4): 540-543, 2019.

16. González-Badillo JJ, Sánchez-Medina L. Movement velocity as a measure of loading intensity in resistance training. Int J Sports Med 31(5): 347-352, 2010.

17. Goodin J, Bernards J, Travis K, Stone M. Intraset variability of concentric mean velocity in the back squat. In: 11th Annual Coaching and Sport Science College. Johnson City, TN: East Tennessee State University, 2016.

18. Hopkins W, Marshall S, Batterham A, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc 41(1): 3, 2009.

19. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med 15(2):155-163, 2016.

20. Lorenzetti S, Lamparter T, Lüthy F. Validity and reliability of simple measurement devices to assess the velocity of the barbell during squats. BMC Res Notes 10(1): 707-74, 2017.

21. Mann B. Developing explosive athletes: Use of velocity based training in athletes. Ultimate Athlete Concepts; 2016.

22. Mann JB, Ivey PA, Sayers SP. Velocity-based training in football. Strength Cond J 37(6): 52-57, 2015.

23. Martínez-Cava A, Morán-Navarro R, Sánchez-Medina L, González-Badillo JJ, Pallarés JG. Velocity-and power-load relationships in the half, parallel and full back squat. J Sports Sci 37(10): 1088-1096, 2019.

24. McBride JM, Triplett-McBride T, Davie A, Newton RU. The effect of heavy vs. light-load jump squats on the development of strength, power, and speed. J Strength Cond Res 16(1): 75-82, 2002.

25. Mitter B, Hölbling D, Bauer P, Stöckl M, Baca A, Tschan H. Concurrent validity of field-based diagnostic technology monitoring movement velocity in powerlifting exercises. J Strength Cond Res 35(8): 2170-2178, 2021.

26. Moreno-Villanueva A, Pino-Ortega J, Rico-González M. Validity and reliability of linear position transducers and linear velocity transducers: A systematic review. Sports Biomech: 1-30, 2021.

27. Nagata A, Doma K, Yamashita D, Hasegawa H, Mori S. The effect of augmented feedback type and frequency on velocity-based training-induced adaptation and retention. J Strength Cond Res 34(11): 3110-3117, 2020.

28. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1): 1, 2019.

29. Orange ST, Hritz A, Pearson L, Jeffries O, Jones TW, Steele J. Comparison of the effects of velocity-based vs. traditional resistance training methods on adaptations in strength, power, and sprint speed: A systematic review, meta-analysis, and quality of evidence appraisal. J Sports Sci: 1-15, 2022.

30. Pareja-Blanco F, Rodríguez-Rosell D, Sánchez-Medina L, Sanchis-Moysi J, Dorado C, Mora-Custodio R, Yáñez-García JM, Morales-Alamo D, Pérez-Suárez I, Calbet J. Effects of velocity loss during resistance training on athletic performance, strength gains and muscle adaptations. Scand J Med Sci Sports 27(7): 724-735, 2017.

31. Sánchez-Medina L, González-Badillo J, Pérez C, Pallarés J. Velocity-and power-load relationships of the bench pull vs. bench press exercises. Int J Sports Med 34(3): 209-216, 2013.

32. Sato K, Beckham GK, Carroll K, Bazyler C, Sha Z. Validity of wireless devices measuring velocity of resistance exercises. J Trainol 4(1): 15-18, 2015.

33. Suchomel TJ, Nimphius S, Bellon CR, Hornsby WG, Stone MH. Training for muscular strength: Methods for monitoring and adjusting training intensity. Sports Med 51(10): 2051-2066, 2021.

34. Swinton PA, Hemingway BS, Saunders B, Gualano B, Dolan E. A statistical framework to interpret individual response to intervention: Paving the way for personalized nutrition and exercise prescription. Front Nutr 5: 41, 2018.

35. Thompson SW, Rogerson D, Dorrell HF, Ruddock A, Barnes A. The reliability and validity of current technologies for measuring barbell velocity in the free-weight back squat and power clean. Sports 8(7): 94, 2020.

36. Walter S, Eliasziw M, Donner A. Sample size and optimal designs for reliability studies. Stat Med 17(1): 101-110, 1998.

37. Weakley J, Mann B, Banyard H, McLaren S, Scott T, Garcia-Ramos A. Velocity-based training: From theory to application. Strength Cond J 43(2): 31-49, 2021.

38. Weir JP. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. J Strength Cond Res 19(1): 231-240, 2005.

39. Weir JP, Vincent WJ. Statistics in kinesiology. Champaign, IL: Human Kinetics; 2020.

40. Włodarczyk M, Adamus P, Zieliński J, Kantanista A. Effects of velocity-based training on strength and power in elite athletes—a systematic review. Int J Environ Res Public Health 18(10): 5257, 2021.

41. WMA. World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. JAMA 310(20): 2191-2194, 2013.