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Journal article

Validity and test-retest reliability of the 1080 quantum system for bench press exercise

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Title: Validity and test-retest reliability of the 1080 Quantum System for bench press exercise

Running Head: Validity and reliability of 1080 Quantum

ABSTRACT

This study assessed the validity and reliability of the 1080 Quantum (1080Q) during the bench press exercise. Twenty-seven resistance-trained men (28 ± 4 years; body mass 88.9 ± 12.8 kg; 1RM bench press 94.8 ± 10.7 kg) completed two test-retest sessions, separated by one week. In each session participants performed single repetitions at 30, 40, 50, 60, 70 and 80% of their bench press 1-repetition maximum (1RM). Mean velocity (V_{mean}), peak velocity (V_{peak}), mean force (F_{mean}), peak force (F_{peak}), mean power (P_{mean}) and peak power (P_{peak}) were simultaneously assessed using the 1080Q Synchro and a linear position transducer (GymAware). The overall performance of the 1080Q was both valid ($r = 0.94-1.00$) and reliable ($CV = 1.7-8.0\%$, $ICC = 0.90-1.00$) for all measures, although both fixed and systematic biases were present. When assessed at each of the relative loads, the 1080Q remained valid for all measures apart from F_{mean} at 30% 1RM ($r = 0.78$) and F_{peak} at 70 ($r = 0.81$) and 80% ($r = 0.57$) 1RM. The 1080Q also demonstrated excellent reliability at all relative loads apart from the heaviest, where V_{mean} ($CV = 11.0\%$, $ICC = 0.69$), P_{mean} ($CV = 11.4\%$, $ICC = 0.65$) and P_{peak} ($CV = 10.2\%$, $ICC = 0.79$) reliability was reduced. These data indicate that athletes and strength and conditioning coaches can confidently use the 1080Q to monitor training progression, however, caution should be taken when assessing performance measures at the either end of the load spectrum.

Keywords: Linear position transducer, power, velocity, force

INTRODUCTION

Strength and power are critical for optimal sporting performance. As such, the measurement and development of these qualities is a major focus of strength and conditioning practitioners, not only for the assessment of a training programs effectiveness, but also for the identification of athletic talent, diagnosis of a specific deficiencies within an athlete and the monitoring of injury recovery (1, 20). Resistance training (RT) is integral to the development of strength and power. Traditionally, RT has been prescribed and monitored through the use of variables such as volume (i.e., sets and repetitions) and intensity (percentage of one repetition maximum, %1RM) (25). However, while this approach provides a method of load monitoring that is simple to calculate and easily applied in the field, it may underestimate exercise intensity as it ignores the length of rest between sets and velocity of movement (25).

Movement velocity is closely related to the relative load of a given exercise (10, 11). Indeed, the velocity of movement at 1RM appears to be similar between individuals irrespective of absolute strength, and remains stable at a given relative load despite improvements in strength (10). Furthermore, strong relationships exist between the loss in velocity and proportion of total possible reps completed, as well as metabolic markers of neuromuscular fatigue (24). These results suggest that changes in movement velocity may be a more objective way to quantify the intensity of a RT session. However, to be of use to practitioners, practical, valid and reliable methods for assessing movement velocity must be available.

Linear position transducers (LPT) are becoming an increasingly popular and affordable tool for the measurement of movement velocity, force and power in both laboratory and applied

settings. These devices are relatively simple to use and offer immediate feedback to the athlete and coach; providing motivation and the ability to maximize training on a rep by rep basis. An LPT uses a rotational sensor to measure the displacement of a retractable cable tethered to either an individual or barbell. From displacement, velocity and acceleration can be derived and force and power subsequently calculated (12). The validity and reliability of commercially available LPT have been repeatedly demonstrated, across a range of resistance exercises in comparison to the 'gold standard' laboratory-based measures of a force plate and 3D motion capture systems (2, 8, 9).

Recently, linear position technology has been fused with a robotic electric motor to generate a device that combines both testing and RT functions. The 1080 Quantum (1080Q) looks like a classic pulley machine with a cable that attaches to either a barbell or individual, but can be independently controlled to allow varying degrees of electromagnetic resistance during concentric and eccentric movement phases, as well as create different modes of training (e.g. isokinetic, isotonic, regular mass, and vibration) (3). Velocity is determined via an optical encoder measuring the position of the motor axis, which is used to calculate speed and acceleration through differentiation of position with regard to time. However, rather than calculating force from the differentiated data, it is instead determined based on the amount of current and voltage sent to the motor by the servo drive. The actual torque of the motor shaft can then be determined and power measures ultimately calculated using the product of speed and force (3). By combining two of the 1080Q units using a Smith machine, the performance of classic barbell exercises, such as a squat or bench press is possible. While still a relatively new device, isokinetic training performed using the 1080Q has been shown to provide a greater improvement in vertical jump and sprint performance compared to

traditional Olympic and free weight lifting (13). However, to date the validity and reliability of the 1080Q has not been independently demonstrated. Therefore the purpose of the current study was to determine the concurrent validity and test-retest reliability of mean and peak velocity, force and power measurements obtained with the 1080Q during the bench press exercise in resistance trained individuals.

METHODS

Experimental approach to the problem

To determine the concurrent validity and test-retest reliability of the 1080Q (1080 Motion, Sweden) we assessed velocity, force and power measures obtained during the bench press exercise on two separate days. A minimum of 48 h following the preliminary familiarization and testing sessions, subjects completed two experimental trials, each separated by a week. In each trial, subjects performed a single bench press repetition at 10% increments of their Smith machine bench press 1-repetition max (1RM), starting at either 30 or 40% 1RM, depending on their 1RM. Validity was assessed in the first experimental session by comparing measurements simultaneously obtained using the 1080Q and a linear position transducer (GYM; GymAware, Kinetic Performance Technology, Canberra, Australia). Test-retest reliability was determined by comparing the measures obtained in each of the experimental trials.

Subjects

Twenty seven recreationally active males (mean \pm SD; age, 28 ± 4 years; body mass, 88.9 ± 12.8 kg;) volunteered to participate in the study. All subjects were free from any upper body injuries, had at least 1 year of resistance training experience and were familiar with the free-

weight bench press exercise. While all subjects completed the trials, technical issues resulted in the exclusion of 1 subject's data from the final analysis. Therefore, the data reported represent an $n = 26$. Subjects were required to have a 1RM for the bench press >75 kg (1RM, 94.8 ± 10.7 kg). This inclusion criteria was required as the minimum possible weight for the 1080Q Synchro set up is 30 kg and the experimental design required testing across a range of loads between 40-80% 1RM (i.e., $30 \text{ kg} / 0.4 = 75 \text{ kg}$). Subjects were recruited via advertisements in local gyms and on social media platforms. All subjects were informed of the benefits and risks of participating in the study prior to providing their written, informed consent, using an institutionally approved consent document. While subjects continued to pursue their individual training programs throughout the experiment they were encouraged not to perform any form of training 48 h prior to each of the testing sessions. All tests were conducted at approximately the same time of day (± 2 h) and under similar environmental conditions ($18\text{-}22^\circ\text{C}$). The study was conducted in accordance with the Declaration of Helsinki, and all protocols were approved by the XXXXX University Human Research Ethics Committee and XXXXXX.

Procedures

Familiarization

Prior to 1RM testing, all subjects performed one session to become familiar with the 1080Q, as well the bench press exercise utilizing a Smith machine. The Smith machine was used in order to restrict displacement of the bar to the vertical plane and increase the accuracy of the GYM measures. This session included a general warm up followed by 4 sets of 3-5 repetitions with a self-selected load of between 40-80% of subjects estimated 1RM.

1RM Testing

Each subject's 1RM for the Smith machine bench press exercise was determined following the protocol outlined by McGuigan et al (21). Subjects first performed a general aerobic warm-up (5-10 min), followed by a specific warm up consisting of 10 repetitions of the bench press exercise using the 1080Q at 40% to 60% of their estimated 1RM. After 2 min of passive rest, subjects completed an additional 5 repetitions at 60% to 80% 1RM. Following a further 2 min rest, the process was repeated at 90% 1RM for a maximum of 3 repetitions. After an extended rest period of 5 min they attempted their first 1RM trial. According to the outcome of the attempt the subsequent trial was completed with either an increased or decreased load. This process was repeated, with 5 min rest between lifts, until the 1RM was determined.

Testing Protocol

Both cables from the 1080Q were attached to either end of the Smith machine barbell, perpendicular with the floor (Figure 1A). The cable from the GYM was positioned ~10 cm lateral to that of the 1080Q (Figure 1B). Both systems were calibrated prior to each testing session following the manufacturer's instructions. The GYM has previously been demonstrated to be valid and reliable (2, 7).

After a standardized warm up consisting of 10 min aerobic work, shoulder girdle preparation exercises, and two sets of bench press using the 1080Q (10 repetitions at 40% 1RM), all participants were asked to perform a single repetition with five different loads (26). Loads utilized were 40%, 50%, 60%, 70%, and 80% of 1RM. Due to the minimum possible weight (30 kg) of the 1080Q, an initial repetition at 30% 1RM was only completed by subjects with a 1RM > 100kg (n = 11) at the start. Each trial was interspersed with a 2 min passive rest. All

participants lay supine on a bench with their feet on the ground and hands on the bar using a pronated grip. The width of the grip was self-selected, but maintained across all test sessions. When instructed by the investigator, the subject commenced lowering the bar (2 s count) until it touched the chest. Subjects then pressed vertically, with maximal voluntary speed, until the elbows were fully locked. Load order was not randomised and progressed from lighter to heavier weights to minimise any potential impact of fatigue on performance.

INSERT FIGURE 1 HERE

Statistical Analysis

All data are presented as mean \pm standard deviation unless stated otherwise. The validity and reliability analysis were both conducted using customized excel spreadsheets (15). All data were log-transformed to account for non-uniformity of error. The variables used for assessments of both validity and reliability were mean (F_{mean}) and peak force (F_{peak}), velocity (V_{mean} ; V_{peak}), and power (P_{mean} ; P_{peak}). Data were assessed at each individual load ($n=26$) as well as collapsed across all loads ($n=141$).

Concurrent validity of the 1080Q in comparison to the GYM was determined using Pearson product-moment correlation analysis (r) and the standardized typical error of the estimate (TE), both with 95% confidence intervals (95% CI). Using the same criteria as outlined in Banyard et al (2017), the 1080Q was considered highly valid for a given measure if the following 3 criteria were met: a very high correlation ($r > 0.70$), a $CV \leq 10\%$ and a small effect size based on Hopkin's modified Cohen scale (<0.20 *trivial*; $0.20-0.59$ *small*; $0.60-1.19$ *moderate*; $1.20-1.99$ *large*; $2.00-3.99$ *very large* or; >4.00 *extremely large*)(15). The presence

of any fixed and proportional bias between the two instruments was determined using ordinary least products (OLP) regression (18). Fixed bias was identified when the 95% CI of the intercept (a') did not contain zero, and proportional bias was identified when the slope (b') did not contain one (18). Limits of agreement between the GYM and 1080Q were assessed using Bland-Altman plots (4, 19)

Test-retest reliability was assessed using the change in mean, typical error (TE) expressed in both absolute and relative (CV%) values along with the intraclass correlation coefficient (ICC). Estimated ICC were interpreted as poor (<0.5), moderate (0.5 to 0.74), good (0.75 to 0.9) and excellent (>0.9) (16). Variables were considered reliable if the CV was $\leq 10\%$ (5). Additionally, the magnitude between the smallest worthwhile change (SWC), calculated as $0.2 \times$ the between subject standard deviation, and TE was assessed to identify variables that are capable of detecting the SWC for athletic performance. Variables were considered capable of identifying the SWC if the TE was $< \text{SWC}$ (5).

RESULTS

Average (mean \pm SD) values for each relative load obtained in the GYM and 1080Q trials are shown in Figure 2. A significant difference ($P < 0.01$) between the values obtained by the GYM and 1080Q was seen across all variables. The OLP analysis revealed a fixed bias in the overall data of all variables except V_{mean} , although the fixed bias associated with V_{peak} was negligible (Table 1). A proportional bias was also present in all the variables, with the 1080Q providing progressively higher values for F_{mean} , P_{mean} , and P_{peak} , but progressively lower values for F_{peak} (Figure 3 and 4) as load increased. While a proportional bias was found for V_{peak} and V_{mean} these were relatively small. The data for all variables was heteroscedastic,

with an increasing scatter of differences as the load increased (Figure 4). Despite the observed biases, based on the outlined criteria the overall performance of the 1080Q was highly valid when compared to the GYM with Pearson r (0.94-1.00), %CV (2.4-8.9), and ES (0.06-0.37) values all within the appropriate limits (Figures 5-7). When assessed at each of the different relative loads, V_{mean} , V_{peak} , P_{mean} and P_{peak} (Figures 5-7) remained valid. However, F_{mean} was valid for all but the lightest load (30% 1RM), where only a moderate effect size and *high* correlation were obtained (Figure 6A). In contrast, the two heaviest loads (70 and 80% 1RM) were not valid for F_{peak} with only *moderate-high* correlations, *moderate to large* ES and a CV>10% (Figure 6B).

INSERT TABLE 1 HERE

INSERT FIGURES 2 – 7 HERE

Test-retest reliability variables for the 1080Q are shown in Table 2. When combined across all loads, variables measured by the 1080Q showed good reliability (CV, 1.7-8.0%; ICC, 0.90-1.00), yet only measures of V_{mean} , V_{peak} and F_{mean} were capable of detecting the SWC, with a TE < SWC. When individual loads were considered, all variables again showed good reliability (CV < 10%), apart from the 80% 1RM load where the reliability of V_{mean} , P_{mean} and P_{peak} was marginal (CV 10.2-11.4%). The ICC's for individual loads ranged between 0.45-0.99 and tended to be lowest for V_{mean} and V_{peak} . Only F_{mean} was capable of detecting the SWC for athletic performance, with a TE < SWC for loads between 40-80% 1RM.

INSERT TABLE 2 HERE

DISCUSSION

The assessment of strength and power is an integral part of an athletes monitoring program. As such, it is critical athletes and strength and conditioning practitioners are confident that the tools they use are both valid and reliable. This study investigated the concurrent validity and test-retest reliability of the 1080Q device. The results demonstrate the 1080Q provides valid measures of both kinetic and kinematic variables, across a range of relative loads, during bench press exercise in trained individuals. Test-retest reliability of mean and peak velocity, force and power variables were also good, with CV < 10% across all but the heaviest relative loads.

Mean and peak velocity were *perfectly* correlated with the GYM and showed minimal if any fixed or proportional bias (Table 1). A strong degree of validity was also found when V_{mean} and V_{peak} were considered at each of the different loads (Figure 5). Whereas the absolute V_{mean} (-0.05 to -0.1 m.s⁻¹) and V_{peak} (-0.04 to -0.12 m.s⁻¹) reported in the current study were slightly less than those observed previously (10, 11, 23, 26), the expected decrease in velocity with increases in load were similar. While we did not directly assess displacement in the current study (i.e., 3D-motion analysis), previous work has demonstrated very low TE for measures of displacement, V_{mean} and V_{peak} in the GYM when compared to a calibration rig (27). Similarly, in laboratory settings, a strong relationship has been shown between displacement, V_{mean} and V_{peak} values during bench press (7) and back squats (2) obtained with the GYM and either a three-dimensional motion capture system or combination of force plate and four LPT, respectively; indicating the suitability of the GYM as a criterion in the current study. Therefore, the data from the current study indicate the 1080Q is a valid tool for the monitoring of velocity based training.

Measures of overall mean and peak force and power obtained with the 1080Q were valid. However, ordinary least products regression revealed fixed and proportional biases in both force and power when compared to the GYM (Table 1). The 1080Q reported F_{mean} data, on average, ~ 115 N higher than those obtained with the GYM, but despite this bias F_{mean} appeared valid across all relative loads apart from the lightest. In contrast, F_{peak} was underestimated by the 1080Q when compared to the GYM, with the disparity between the two devices increasing with load (Figure 3E). Subsequently, the two heaviest loads (70 and 80% 1RM), which correspond to the intensity where athletes often train, did not meet the criteria for validity (Figure 6). These differences in force obtained with the two devices are possibly due in part to the different approaches each device uses to determine force. Whereas the GYM calculates force from the double differentiation of displacement data, the 1080Q determines force based on the amount of current and voltage sent to the motor by the servo drive (3, 12). In theory, calculating force independent of velocity would eliminate the potential risk for any errors in the signal to be amplified by the differentiation process (12). However, errors in the displacement signal are minimised by the GYM software through the use of down sampling and strong correlations with F_{mean} and F_{peak} measures obtained with a force plate have been reported for back squat and deadlift exercises (2, 7). Further research, comparing the kinetic variables obtained with the 1080Q to the gold standard of a force plate, across a range of exercises, is therefore needed to better interpret these differences. A possible explanation for the difference in F_{peak} may be slight differences in the identification of the initiation of concentric movement by the software. During the bench press exercise, F_{peak} occurs at the point where the muscle transitions from an eccentric to concentric action and is contracting isometrically (22). A more conservative approach to identifying the start

of concentric movement (i.e., greater degree of displacement) would result in a lower determination of F_{peak} , the disparity of which would increase with increasing load due to the faster decline in force for a given amount of bar movement (22). This hypothesis is supported by the progressively greater TE and CV observed in F_{peak} with increasing load (Figure 6). Thus, while the 1080Q provides a valid means to monitor changes in force and power output, caution is required when comparing absolute values obtained with the 1080Q and other devices.

The second aim of this study was to determine the test-retest reliability of the 1080Q. The small changes in mean between trials and low CV suggest the 1080Q is a reliable tool for monitoring performance variables during the bench press across a range of loads. Overall test-retest reliability of the 1080Q was high and similar to that reported for GYM across a range of resistance exercises (7, 23). When considered at each of the relative loads, reliability of measures remained high except for the heaviest load where the CV for V_{mean} , P_{mean} and P_{peak} exceeded the 10% threshold; yet even at this load the CV was only marginally outside the acceptable limits and did not exceed 11.4%. The relative stability of the different measures found across all loads may not hold true for free-weight bench press exercise. Previous work has shown increased movement of the barbell outside of the vertical plane as relative load increases (17), which would presumably lead to a subsequent reduction in reliability. The use of a Smith machine in the current study largely eliminated any extraneous movement and should have subsequently improved reliability by maintaining a vertical barbell path.

Mean force was the most reliable of all the measures with *excellent* ICC (>0.92) and CV below 2.3%. In comparison, the ICC for V_{mean} ranged from *poor* to *good* and the CV averaged 6.5%. As previously noted, the determination of force independent of cable displacement prevents the amplification of error arising from the double differentiation process and, based on the current data, would suggest it is a more reliable approach as reliability of F_{mean} and F_{peak} remained relatively consistent across the different loads. Indeed, the low TE, at all but 30% 1RM, meant F_{mean} was the only variable capable of detecting the smallest worthwhile change. However, the interpretation of ICC is complicated, as low levels of between subject variance will decrease the ICC despite small differences in trial results (14). Therefore the CV, which expresses the TE in a relative manner, provides a clearer indication of the reliability across the different loads. Based on the CV, mean and peak velocity and power were found to be reliable up to loads of 80% 1RM, although there was a progressive decrease in reliability with increases in load. In contrast, reliability of F_{mean} remained consistent irrespective of load. While very few studies have examined changes in reliability with changes in load, in a similar experimental design to the current study, Stock et al (26) also reported a progressive decline in reliability of V_{mean} with increases in bench press load, and CV values above 10% at loads exceeding 80% 1RM. The reasons for the decline in reliability are unclear. Given that subjects were all currently involved in RT, it is unlikely that fatigue was a factor as each subject completed only 6 lifts with sufficient time for recovery in between each rep. However, it may be that while our participants were regularly involved in RT they were not accustomed to heavy loads that require large and coordinated recruitment of motor unit pools and subsequently not as proficient at this task (6).

There are a number of limitations that need to be considered with regard to the current study. First, this study only considered the validity and reliability of the 1080Q when set to replicate a regular mass. Thus, while the data suggest the 1080Q provides valid and reliable measures of velocity, force and power across a range of loads, it cannot be assumed these findings also hold true in the 1080Q's other operational modes. Second, the use of a Smith machine limited the movement of the cables to the vertical direction. As mentioned previously, this restricted movement should improve reliability by eliminating movement in other planes, especially at higher loads (17). It is possible that other exercises that do not utilise the controlled nature of the Smith machine may display reduced levels of reliability. Given we only tested a single exercise, the results should not be extrapolated to other exercises. Differences in validity and reliability using a LPT have been found between back squat, bench press and deadlift exercise variables within a population (7, 23). Third, in this study we were unable to validate the force data from the 1080Q using a force plate. While, previous studies have demonstrated F_{mean} and F_{peak} obtained using the GYM are highly valid across a wide range of relative loads (20-100% 1RM)(2), indicating the suitability of the GYM as a surrogate benchmark, further studies are needed to directly compare F_{mean} and F_{peak} obtained using the 1080Q to that of the gold standard. Finally, for some of the subjects, the 1080Q needed to be put into second gear in order to utilize an idler pulley to create enough mechanical resistance at higher loads. Although, the manufacturer has stated this does not lead to impaired measuring ability it may provide another possible explanation for the reduced reliability at higher loads; this theory needs to be further investigated in future studies.

In conclusion, the 1080Q provides valid measures of velocity, force and power during the concentric phase of a Smith machine bench press across a range of loads. The 1080Q also

showed good reliability for measures of V_{peak} , F_{mean} , F_{peak} between 30-80% 1RM and V_{mean} , P_{mean} and P_{peak} between 30-70% 1RM. The low TE also indicates the 1080Q is capable of detecting subtle improvements in force generation, although practitioners should be cautious when comparing outputs obtained with the 1080Q to other LPT devices.

PRACTICAL APPLICATIONS

The 1080Q generally provides valid and reliable measures of peak and mean velocity, force and power in the bench press exercise between 30 and 70% 1RM. The high validity observed for V_{mean} and V_{peak} means coaches and athletes can confidently use the 1080Q to monitor velocity on a rep by rep basis, as part of a velocity-based training program. The high reliability of measures obtained with the 1080Q also means it has the capability to identify small but important improvements in force production across a range of velocities, making the 1080Q a useful tool for testing the efficacy of a RT program. However, strength and conditioning practitioners should be cautious when comparing force and power data from 1080Q with that from other testing equipment as systematic and proportional biases exist.

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Figure 1

1080 Quantum system (1080Q) and Smith machine setup used in the experiment (A).

Gymaware (GYM) linear position transducer attached to 1080Q (B).

Figure 2

Mean and peak velocity, force and power values obtained using the Gymaware linear position transducer (GYM, ●) and 1080 quantum (1080Q, ○). All data are mean \pm SD. 1RM, 1-repetition maximum. # $P < 0.01$; * $P < 0.001$.

Figure 3

Relationship between the Gymaware linear position transducer (GYM) and 1080 Quantum (1080Q) across all loads for mean velocity (A), mean force (B), mean power (C), peak velocity (D), peak force (E) and peak power (F) using ordinary least products (OLP) regression. The solid and dashed lines represent the line of regression and line of identity, respectively.

Figure 4

Limits of agreement between the Gymaware (GYM) linear position transducer and 1080 quantum (1080Q). The solid and dashed lines represent the ordinary least squares line of best fit and the upper and lower 95% confidence intervals, respectively.

Figure 5

Validity of the bench press mean (A) and peak (B) velocity for 1080 Quantum (1080Q) compared to the Gymaware linear position transducer (GYM) overall and at 30, 40, 50 60 , 70 and 80% of 1-repetition max (1RM). Forest plots represent Pearson correlation coefficient, coefficient of variation (CV), effect size estimates (ES) and typical error of the estimate (TE). Error bars indicate 95% confidence intervals.

Figure 6

Validity of the bench press mean (A) and peak (B) force for 1080 Quantum (1080Q) compared to the Gymaware linear position transducer (GYM) overall and at 30, 40, 50 60 , 70 and 80% of 1-repetition max (1RM). Forest plots represent Pearson correlation coefficient, coefficient of variation (CV), effect size estimates (ES) and standard error of the estimate (TE). Error bars indicate 95% confidence intervals.

Figure 7

Validity of the bench press mean (A) and peak (B) power for 1080 Quantum (1080Q) compared to the Gymaware linear position transducer (GYM) overall and at 30, 40, 50 60 , 70 and 80% of 1-repetition max (1RM). Forest plots represent Pearson correlation coefficient, coefficient of variation (CV), effect size estimates (ES) and standard error of the estimate (TE). Error bars indicate 95% confidence intervals.

Accepted

Figure 1



Accepted

Figure 2

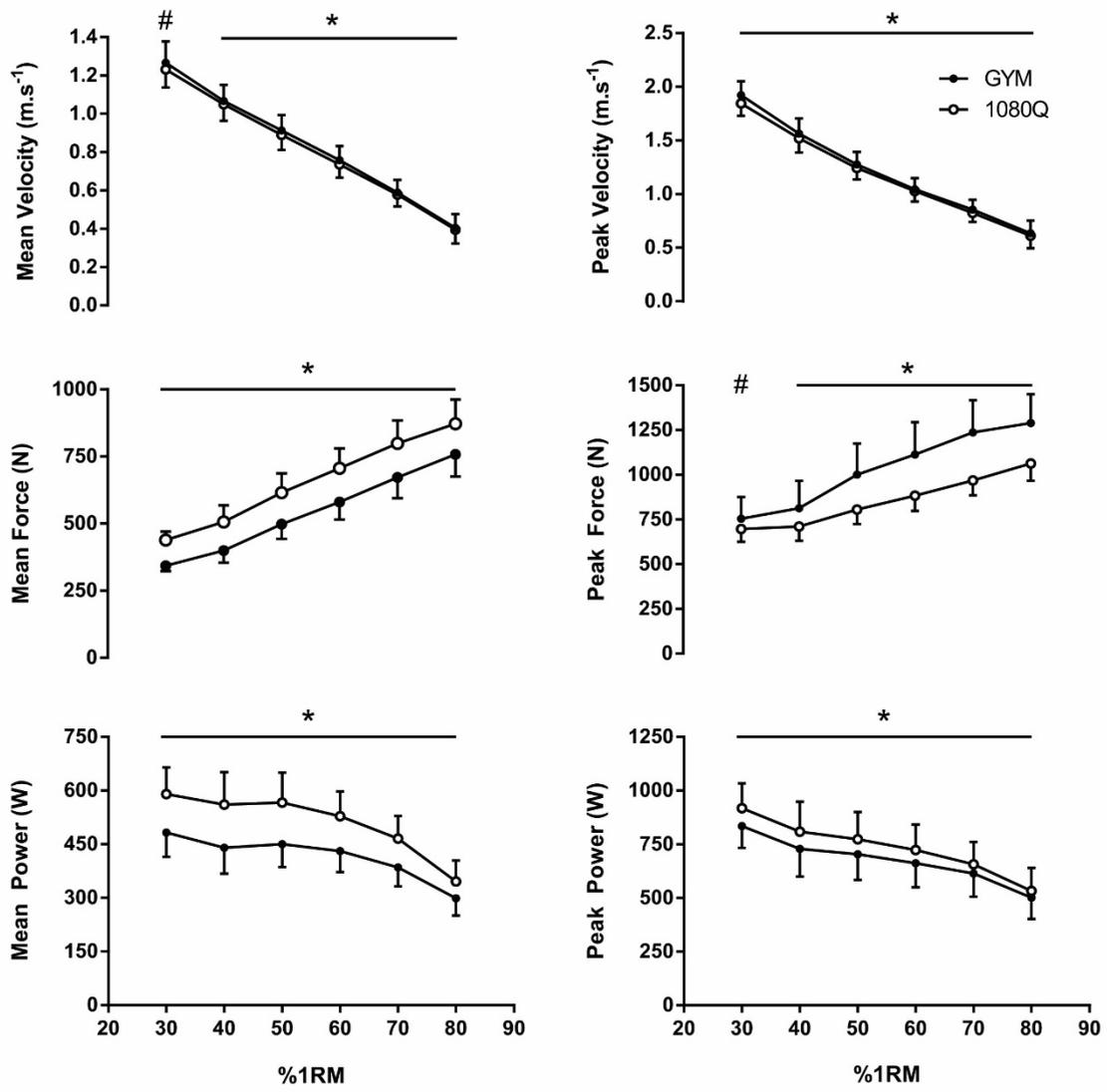


Figure 3

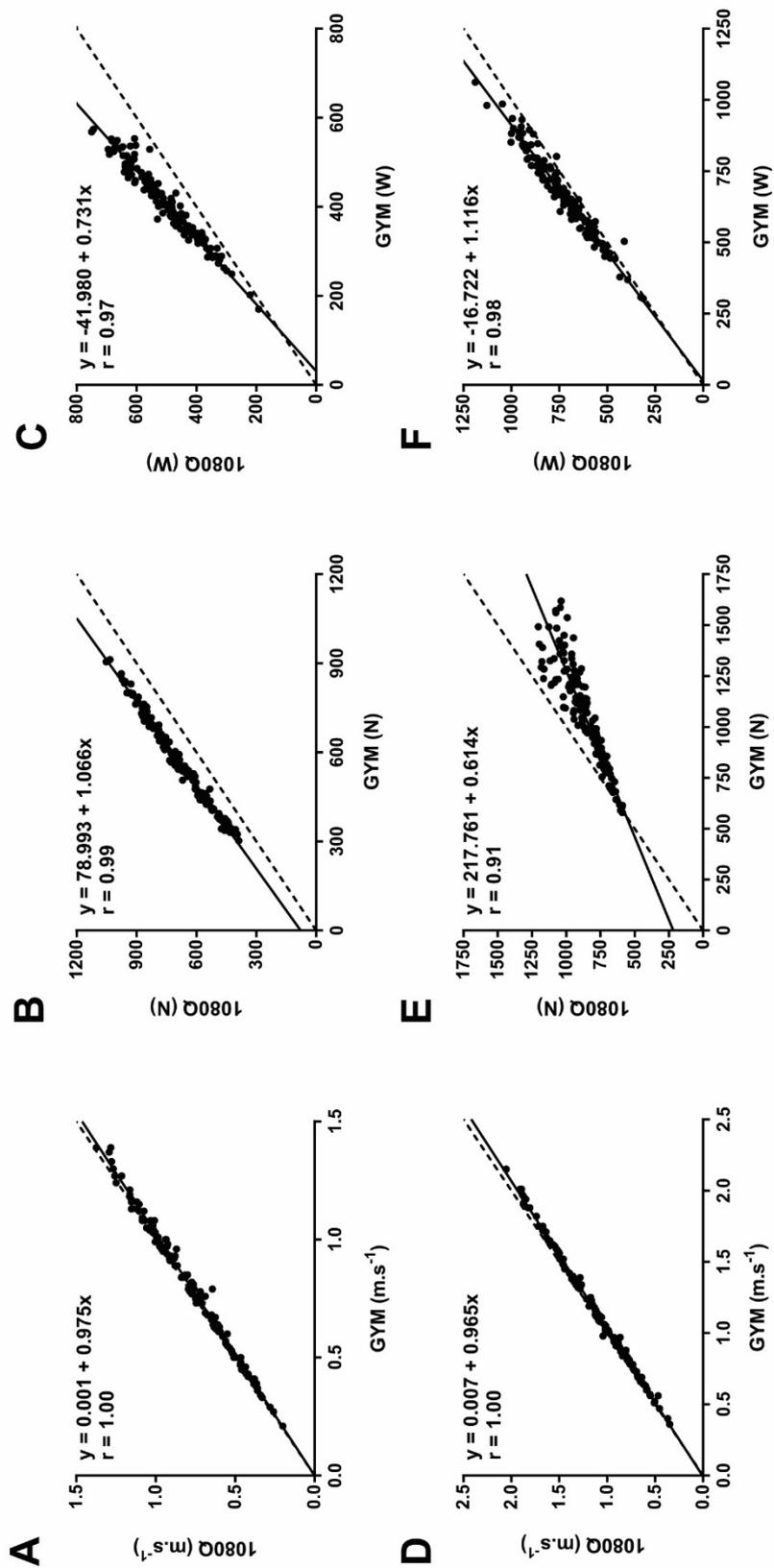


Figure 4

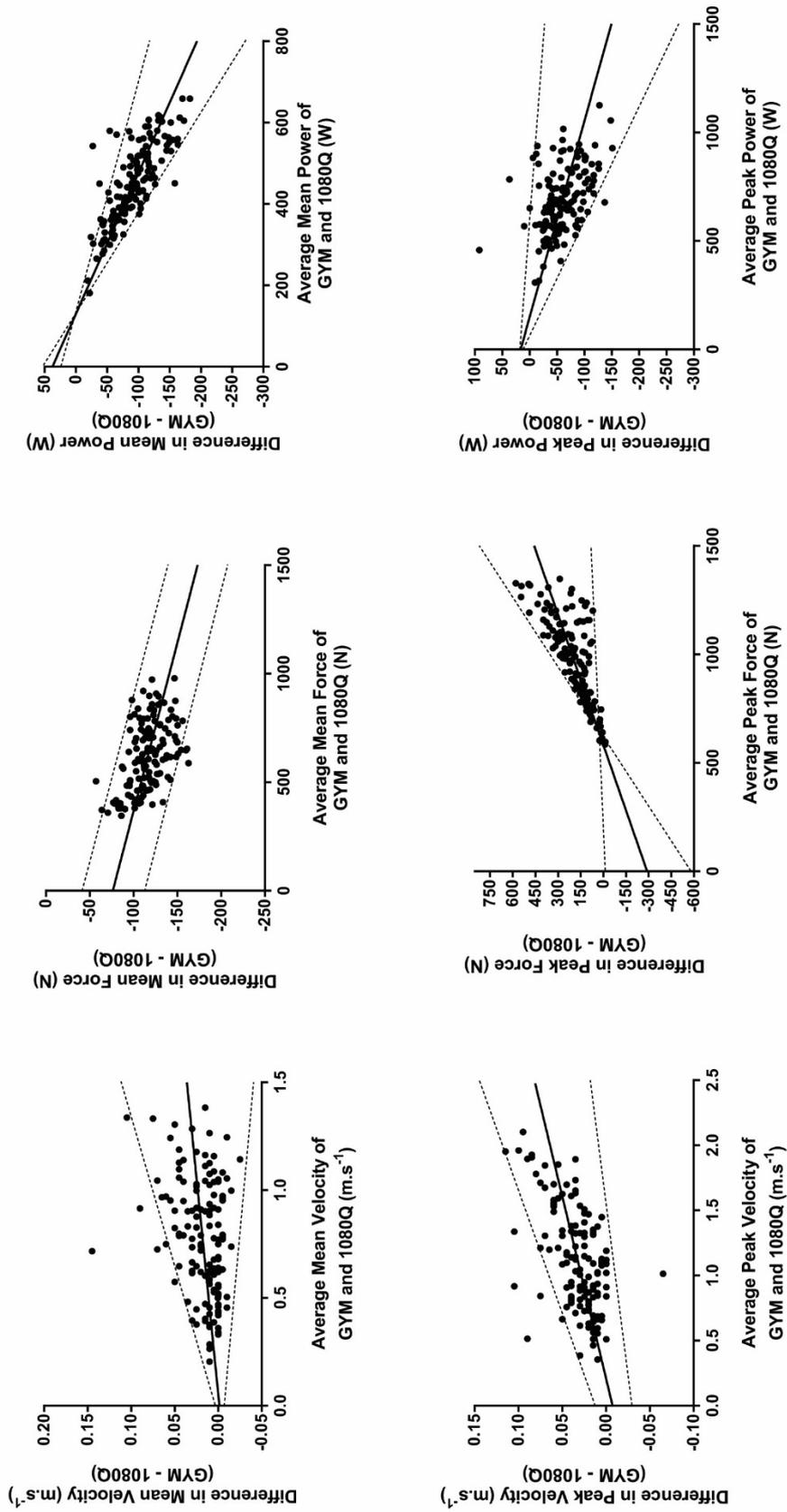


Figure 5

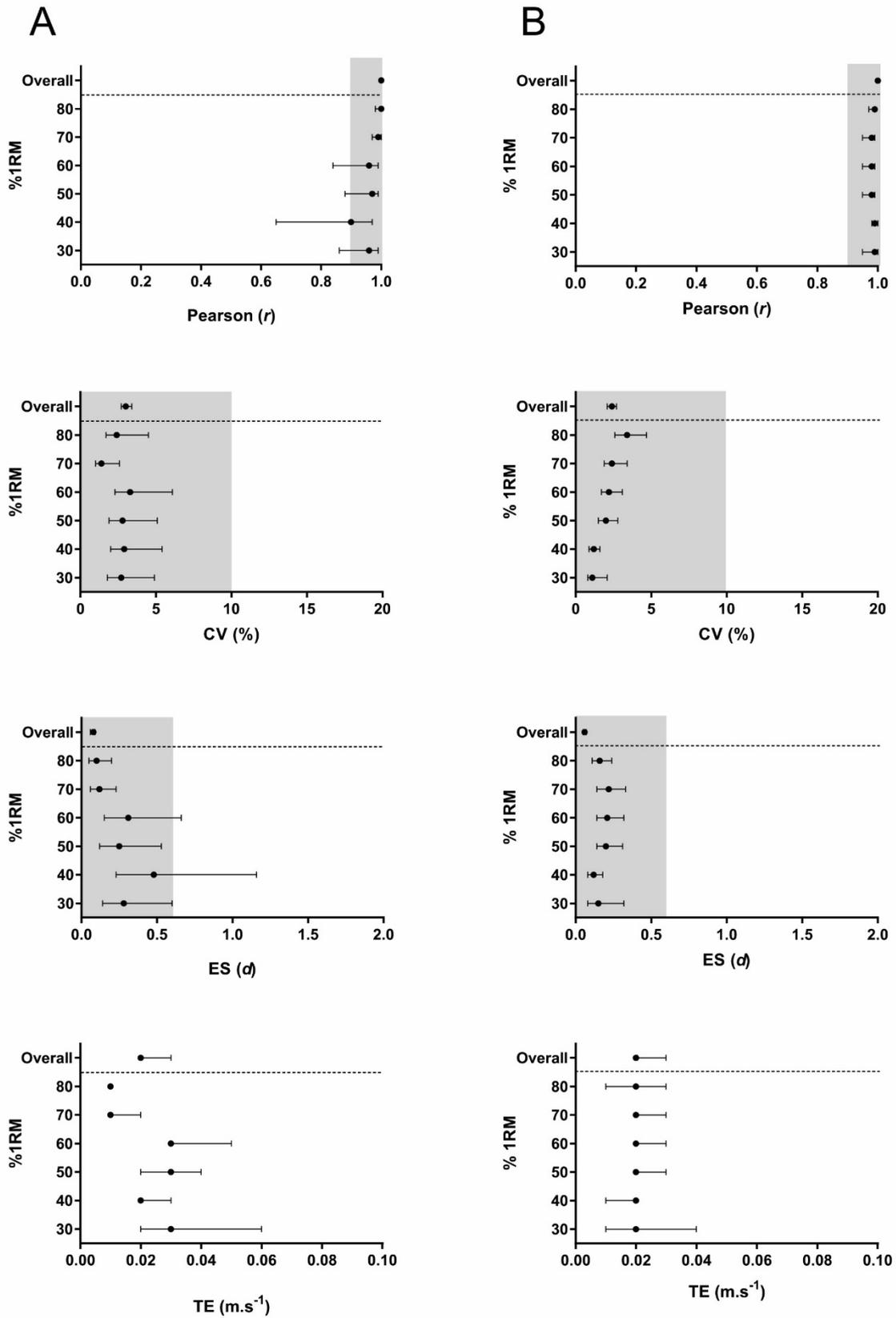


Figure 6

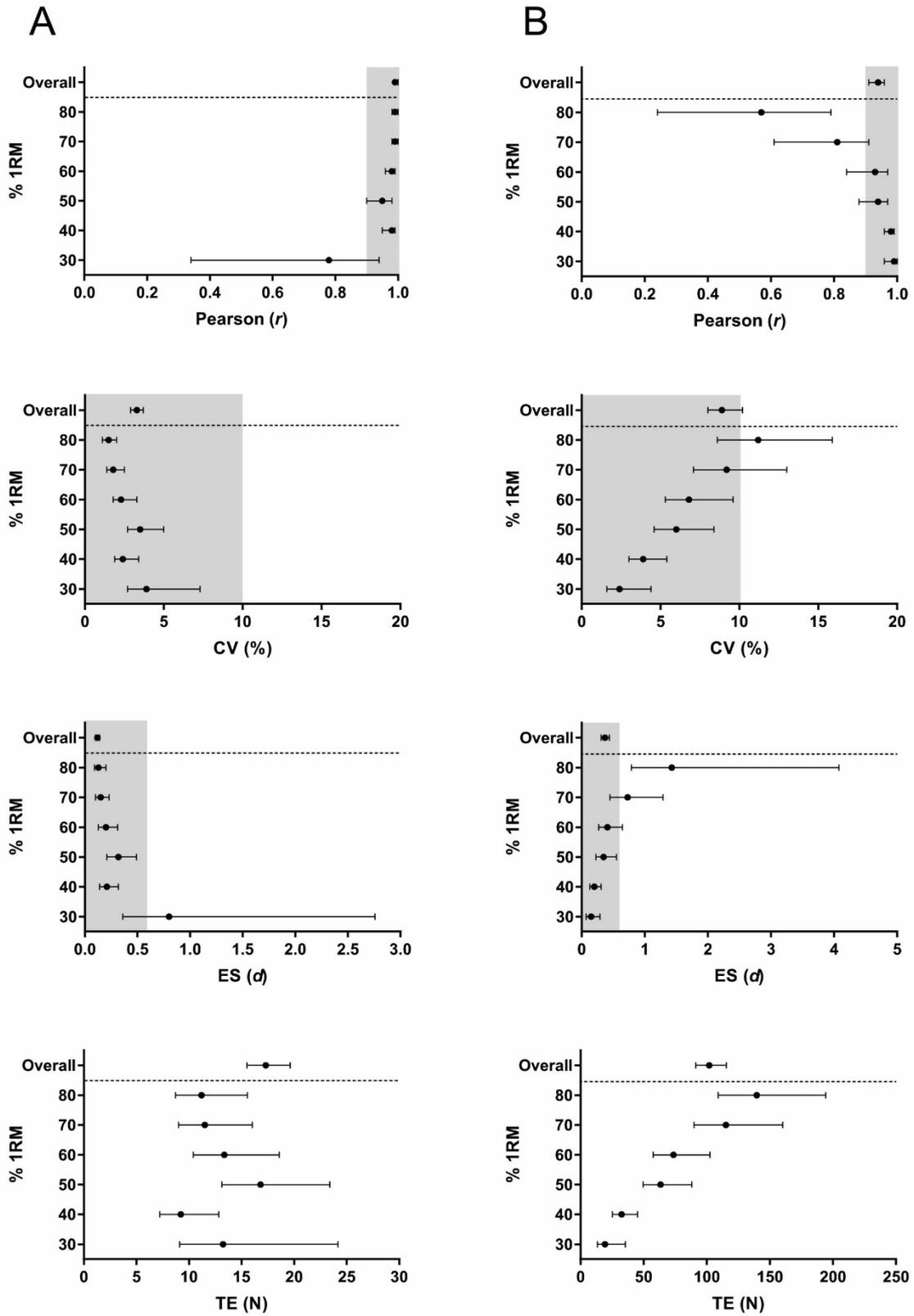


Figure 7

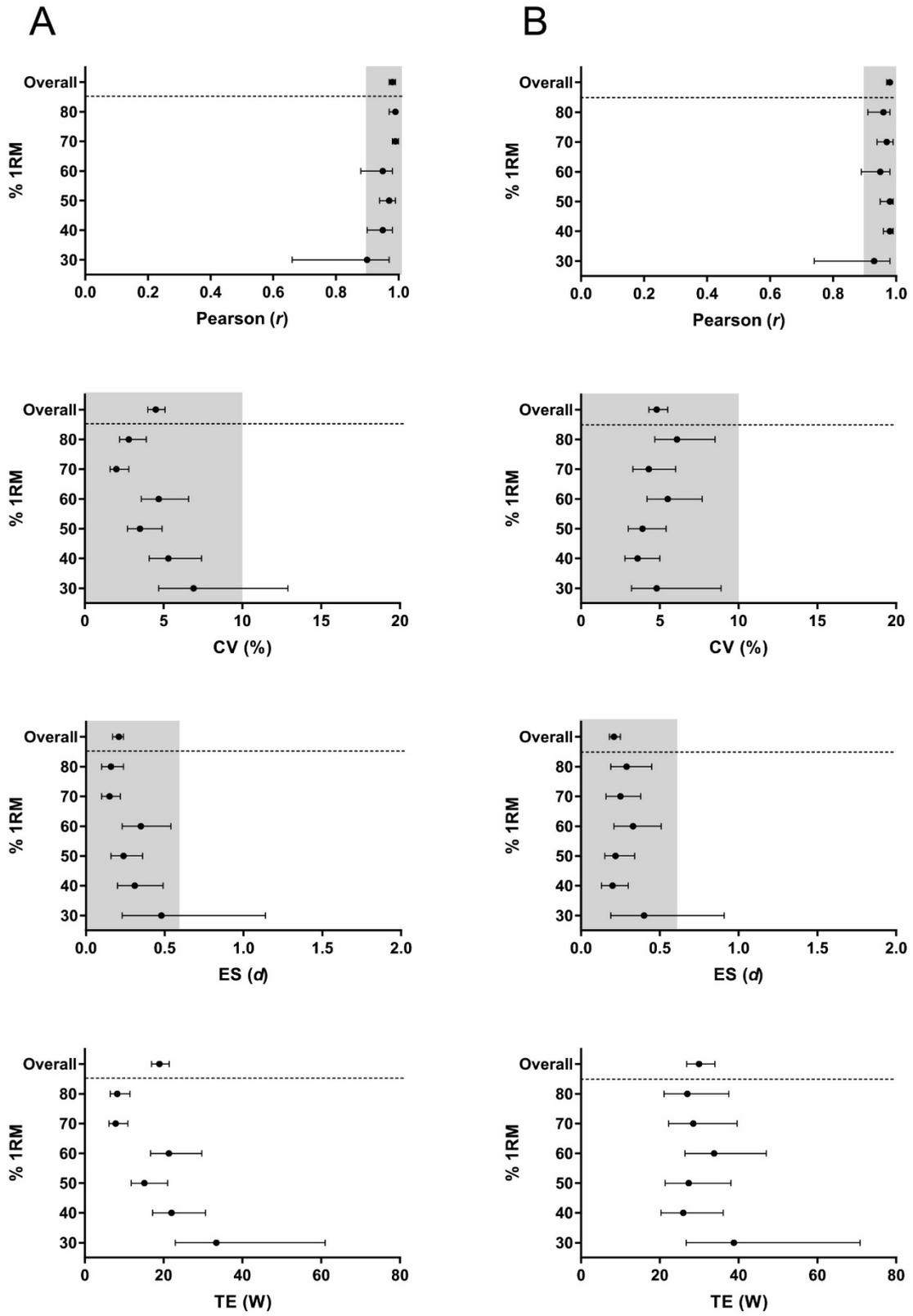


Table 1: Mean difference and ordinary least products regression of velocity, force and power variables obtained using the Gymaware linear position transducer and 1080Q across all loads.

Variable	Mean Difference	a'	95% CI for a'	b'	95% CI for b'	Fixed Bias	Proportional Bias
Mean Velocity (m.s ⁻¹)	0.018 ± 0.024	0.001	-0.004, 0.007	0.975	0.968, 0.983	No	Yes
Mean Force (N)	-116.3 ± 20.5	79.0	73.2, 84.7	1.066	1.056, 1.077	Yes	Yes
Mean Power (W)	-93.8 ± 35.3	-42.0	-52.6, -31.9	1.333	1.308, 1.359	Yes	Yes
Peak Velocity (m.s ⁻¹)	0.033 ± 0.026	0.007	0.002, 0.012	0.965	0.960, 0.970	Yes	Yes
Peak Force (N)	193.0 ± 126.2	217.8	194.3, 238.9	0.614	0.594, 0.636	Yes	Yes
Peak Power (W)	-59.2 ± 35.9	-16.7	-29.7, -4.4	1.116	1.10, 1.14	Yes	Yes

a' , y-intercept; b' , slope; fixed bias, if 95% CI for a' does not include 0; proportional bias, if 95% CI for b' does not include 1. Mean difference data are presented as mean ± standard deviation.

Table 2: Test-retest reliability assessment of individual loads for the 1080 Quantum

	% 1RM	Mean	Mean Δ	Lower 95% CL	Upper 95% CL	ICC _{3,1}	Lower 95% CL	Upper 95% CL	TE	Lower 95% CL	Upper 95% CL	SWC	CV%
Mean Velocity (m.s⁻¹)	OA	0.771	0.004	-0.006	0.015	0.97	0.96	0.98	0.043	0.038	0.049	0.054	7.0
	30	1.229	-0.003	-0.054	0.047	0.64	0.10	0.89	0.053	0.037	0.093	0.017	4.5
	40	1.050	0.001	-0.021	0.023	0.82	0.63	0.91	0.039	0.030	0.053	0.017	3.7
	50	0.894	0.010	-0.017	0.037	0.53	0.19	0.76	0.047	0.037	0.065	0.014	5.7
	60	0.743	0.017	-0.010	0.043	0.45	0.08	0.71	0.046	0.036	0.064	0.012	6.5
	70	0.578	0.000	-0.021	0.022	0.63	0.38	0.79	0.045	0.037	0.059	0.014	7.6
	80	0.393	-0.003	-0.020	0.013	0.69	0.46	0.83	0.035	0.028	0.046	0.013	11.0
Mean Force (N)	OA	679	-0.3	-2.8	2.2	1.00	0.99	1.00	10.6	9.5	12.1	32.2	1.7
	30	436	-4.1	-12.5	4.3	0.93	0.77	0.98	8.9	6.2	15.5	6.0	2.0
	40	506	-0.9	-6.5	4.7	0.98	0.95	0.99	9.8	7.7	13.5	12.0	1.9
	50	618	3.4	-4.4	11.1	0.96	0.92	0.98	13.6	10.6	18.7	14.2	2.3
	60	708	3.2	-4.0	10.4	0.98	0.95	0.99	12.6	9.9	17.4	15.3	1.7
	70	796	-4.8	-9.5	-0.1	0.99	0.98	1.00	8.3	6.5	11.4	17.3	1.1
	80	872	-0.9	-5.6	3.8	0.99	0.98	1.00	8.2	6.5	11.4	18.4	0.9
Mean Power (W)	OA	503	3.4	-5.0	11.7	0.90	0.86	0.93	35.4	31.7	40.1	22.4	8.0
	30	588	-4.1	-39.5	31.3	0.73	0.27	0.92	37.2	26	65.3	13.8	6.7
	40	560	-1.6	-17.9	14.7	0.91	0.81	0.96	28.5	22.3	39.3	17.6	5.1
	50	571	8.1	-13.7	29.9	0.79	0.59	0.90	38.1	29.9	52.6	16.7	7.3
	60	536	14.8	-8.4	38.0	0.74	0.50	0.87	40.7	31.9	56.2	15.0	7.6
	70	466	-0.4	-21.9	21.2	0.73	0.48	0.87	37.7	29.6	52.1	13.9	8.3
	80	346	-1.1	-19.2	17.0	0.65	0.36	0.83	31.6	24.8	43.7	11.9	11.4
Peak Velocity (m.s⁻¹)	OA	1.109	0.002	-0.011	0.016	0.97	0.96	0.98	0.058	0.052	0.065	0.078	6.3
	30	1.846	0.002	-0.066	0.070	0.61	0.06	0.88	0.071	0.050	0.125	0.022	4.1
	40	1.521	0.001	-0.030	0.032	0.84	0.67	0.92	0.055	0.043	0.075	0.025	3.6
	50	1.247	0.008	-0.026	0.043	0.68	0.40	0.84	0.061	0.048	0.084	0.020	5.0
	60	1.028	0.000	-0.028	0.029	0.75	0.52	0.88	0.050	0.039	0.069	0.019	5.0

	70	0.827	0.004	-0.037	0.045	0.58	0.26	0.79	0.073	0.057	0.100	0.020	8.2
	80	0.610	-0.001	-0.028	0.026	0.80	0.60	0.90	0.047	0.037	0.064	0.022	9.5
Peak Force (N)	OA	870	-2.6	-11.3	6.0	0.94	0.92	0.96	36.8	32.9	41.6	30.5	4.4
	30	686	-20.9	-65.1	23.2	0.51	-0.10	0.84	46.5	32.5	81.5	12.7	7.0
	40	708	-4.9	-19.3	9.5	0.90	0.80	0.96	25.2	19.8	34.8	15.3	3.5
	50	810	7.4	-14.5	29.2	0.79	0.59	0.90	38.2	30.0	52.8	16.4	4.9
	60	883	1.3	-19.8	22.3	0.80	0.61	0.91	36.8	28.9	50.8	15.8	4.2
	70	968	0.4	-22.3	23.0	0.78	0.57	0.89	39.6	31.0	54.6	16.3	4.3
	80	1059	-9.4	-31.7	12.9	0.87	0.73	0.94	39.0	30.6	53.9	20.2	3.7
	Peak Power (W)	OA	717	2.0	-9.3	13.4	0.91	0.88	0.93	48.2	43.1	54.6	32.9
30		920	2.4	-46.1	50.9	0.79	0.40	0.94	51.1	35.7	89.6	22.5	6.1
40		808	-2.2	-25.1	20.6	0.92	0.84	0.97	40.0	31.4	55.2	27.6	5.1
50		777	6.9	-23.1	36.8	0.85	0.69	0.93	52.4	41.1	72.4	26.2	7.0
60		725	1.3	-22.8	25.3	0.88	0.76	0.95	42.0	33.0	58.0	24.7	6.1
70		657	1.6	-33.0	36.1	0.77	0.55	0.89	60.5	47.5	83.5	23.2	8.9
80		534	2.5	-24.0	29.0	0.79	0.59	0.90	46.4	36.4	64.0	22.2	10.2

CL, confidence limits; CV, coefficient of variation; ICC, intraclass correlation coefficient; mean Δ , mean difference between trials in raw units; TE, typical error of the estimate; SWC, smallest worthwhile change