Criterion Validity of Force and Power Outputs for a Commonly Used Flywheel Resistance Training Device and Bluetooth App

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ABSTRACT

Flywheels are a resistance training device that can increase lean body mass, strength, and power. However, due to their unique design and the inertia from the concentric portion directly relating to the force that is applied during the eccentric portion, monitoring the training stimulus can be difficult. Consequently, the aim of this study was to assess the validity of the kMeter app for quantifying force and power at a range of different isoinertial loads from a flywheel training device when compared against a criterion measure. Eleven subjects volunteered to take part in this study, with subjects completing between 5-35 repetitions of the harness squat with 0.05, 0.10, 0.15 $kg{\cdot}m^2$ isoinertial load. A synchronised dual force plate and tri-camera optoelectronic setup was used as the criterion measure to calculate force and power output, while the kMeter app was used as the practical measure. Very large to nearly perfect relationships were observed between the two measures, with trivial to moderate bias reported. Additionally, typical error of the estimate (TEE) was found to be <10% at all isoinertial loads. These findings suggest that the kMeter app, when used in conjunction with the kBox flywheel device, demonstrate acceptable levels of validity. However, due to the TEE, the kMeter app may not be able to accurately detect small differences and therefore be suitable for research purposes. These findings suggest that the kMeter app is an acceptable method of monitoring flywheel resistance training. Furthermore, it is advised that practitioners utilise mean power rather than mean force.

Keywords: Flywheel; Validity; kBox; kMeter; Force; Power

INTRODUCTION

Quantifying physical stress when training is an important consideration for the practitioner. The accurate quantification of training load enables coaches to determine whether a stimulus is appropriate and whether it meets the training plan requirements. Additionally, training load information is required for the maximization of training outcomes and minimizing negative risk factors (e.g., illness, overtraining, and injury) (2). This information can then be used to inform future training. Therefore, the monitoring of training requires valid tools so that accurate information can be provided. This is true for all training types, including resistance training.

Resistance training is known to enhance strength, power, and lean body mass (8). It is often implemented through the use of isotonic loads (e.g., barbells and dumbbells) that are dependent on gravity and the mass of the object being lifted. However, in recent times, greater attention has been shown to alternatives, such as the flywheel (5, 7). Flywheel training offers accommodated and unlimited resistance during coupled concentric and eccentric muscle actions using the inertia of a rotating wheel (5). This contrasts traditional methods that provide constant-loading across the range of the movement. Yet, due to the unique design of the flywheel (e.g., no external mass is directly lifted, inertia from the concentric action directly affects force in the eccentric action), quantifying this form of training can be difficult. However, advancements in technology may allow for the live monitoring of this form of training.

The kMeter (kMeter II, Exxentric AB, Sweden) is a wireless monitoring device that tracks the rotation of a flywheel and transmits live kinetic (e.g. force), kinematic (e.g. displacement), and repetition (e.g. number of repetitions completed) data via Bluetooth to a freely available smart phone app. This transmitter comes attached with a flywheel resistance training device that is commonly used in both practice and research (kBox, Exxentric AB, Sweden) (2, 6, 7). Furthermore, a recently published study by Bollinger et al. (1) has used the kMeter as a tool to measure test-retest reliability and construct validity of average and peak force and power outputs during eccentric and concentric phases at a range of different loads. However, this study did not compare these outcomes with a criterion measure (i.e., synchronised high-speed camera and force platform setup) but compared outcomes with a rotating wheel of similar dimensions. Therefore, the accuracy of information that is provided to both practitioners and researchers from the app is still unknown. Thus, the aim of this study was to assess the validity of force and power outputs at a range of different isoinertial loads from the kMeter app against a gold standard criterion measure.

METHODS

Experimental Approach to the Problem

The study was designed to evaluate the criterion validity of a commonly used flywheel monitoring system (kMeter II) by assessing its level of agreement with a criterion measure (synchronised dual force plate and high-speed camera setup). All participants were familiar with the flywheel and the exercise being tested (i.e. the harness squat) at each isoinertial load (i.e. 0.05, 0.10, and 0.15kg·m^2). All subjects completed the protocol with a single reflective marker attached to the buckle of the harness that attached directly to the flywheel device. To track velocity, three high-speed cameras sampling at 200 Hz were used, while force was assessed by subjects standing on top of synchronised dual-force platforms.

Subjects

Eleven male university rugby union players between the ages of 19-28 years (mean ± SD; age: 22.3 ± 2.6 years; height 1.80 ± 0.07 m; mass: 91.4 ± 5.9 kg) were recruited to take part in this study. All subjects were familiar with the flywheel device and had regularly used this method of resistance training during the six months prior to the testing occasion. Recruited subjects confirmed that they did not have any current injuries and did not have any diseases prior to study commencement. All experimental procedures were approved by Leeds Beckett University's ethics committee, and written consent was provided by all subjects prior to study initiation.

Procedures

The validity of the kMeter app (version 2.3, Exxentric, Stockholm, Sweden) was assessed against a triggered and synchronised criterion measure of dual force plate (30 cm by 50 cm each, Kistler Type 9260AA, Kistler Instruments, Hampshire, UK) and tri-camera optoelectronic system (Qualisys - Oqus system, software version 2.14) in a university biomechanics laboratory. During the exercise, subjects completed between 5-35 repetitions of the harness squat with 0.05, 0.10, and 0.15 $kg \cdot m^2$ isoinertial loads. Subjects were asked to squat to below parallel for each repetition which was visually monitored by the lead researcher. Each subject was given between 5-10 minutes to recover between sets, with load randomized through a block randomization method (i.e. ABC/BCA/CAB). The force plates were placed on top of the flywheel platform, with cameras one and three set up at 45° angles, and camera two stationed directly in front of each subject/flywheel. Prior to exercise, the subjects stood on top of the force plates which were then zeroed and calibrated. This was to negate subject mass (which is not accounted for within the kMeter app). One (18 mm) reflective marker, which was tracked by the optoelectronic cameras, was placed on the anterior face of the buckle of the kBox harness. This buckle attaches the harness to the rotary strap that is used to create rotational force and was adjusted for each subject so that tension was maintained with both legs extended.

Prior to the start of all sets, the kMeter app was connected via Bluetooth to an iPad (iPad Pro, Apple Inc., Cupertino, California, USA) and the corresponding isoinertial load was recorded. At the beginning of each set, two repetitions were used to increase momentum of the flywheel (these repetitions were not included within the analysis), followed by the number of repetitions that the subject felt comfortable completing. The kinematic data from the tri-camera setup were processed in Qualysis with the digital output from the force platforms synchronised to align at the same time point. Only repetitions that had 100% of all time points tracked were used in the final analysis (i.e. if visual was lost from the reflective marker due to rotation of the buckle or was blocked by a subject's hand or clothing during exercise, the repetition was discarded). This allowed for 180 repetitions to be acquired and used for analysis (50 at 0.05 $kg{\cdot}m^2$, 60 at 0.10 $kg{\cdot}m^2$, and 70 at 0.15 $kg{\cdot}m^2$) with average force and power from each repetition and load used as the dependent variables.

Statistical analysis

Agreement between the criterion measure of force plate and high-speed camera technology and the practical measure of the kMeter were assessed at different isoinertial loads (i.e. 0.05, 0.10, 0.15 $kg{\cdot}m^2$) using an Excel spreadsheet designed to calculate the mean bias ($[x_{diff}/x_{criterion}]$ X 100), typical error of the estimate (TEE; $SD_{diff} / \sqrt{2}$), and Pearson correlation coefficient, all with 90% confidence limits (3). All data were log transformed for analyses to reduce bias as a result of nonuniformity error (100xlog (raw value)), excluding the regression analysis (3). Standardized measures were calculated using back-transformed data based on the Cohen's d effect size principle using the following equation: $([\bar{x}\text{practical}-\bar{x}\text{criterion}] / [\text{SDcriterion}])$. The mean bias and standard error were standardized using the SD of the criterion to allow for qualitative rating. The standardized mean bias was rated as trivial (≤0.19), small (0.20–0.59), medium (0.60–1.19), or large (1.20–1.99) (3). The standardized standard error was rated as trivial (<0.10), small (0.10–0.29), moderate (0.30–0.59), or large (<0.59) (3). The magnitude of correlation was rated as trivial (<0.10), small (0.10–0.29), moderate (0.30–0.49), large (0.50–0.69), very large (0.70–0.89), or nearly perfect (0.90–0.99) (3).

RESULTS

The agreement between the criterion and practical measure of mean force and power at all loads can be found in Table 1. The regression plots for the agreement between the criterion and practical measures are presented in Figure 1. The regression equations, slope, and intercept values are presented in Table 2. Standardized biases ranged from trivial to moderate at all loads, while the standardized TEE ranged from moderate to large. Correlation coefficients of mean force and power at all loads demonstrated very large to nearly perfect relationships between the criterion and practical measure.

insert Table 1 here

insert Figure 1 here

insert Table 2 here

DISCUSSION

The primary finding of this study is that the kMeter app provides acceptable levels of agreement with the criterion measure in both mean force and power at a range of different isoinertial loads. The app demonstrates trivial to moderate levels of bias, TEE <10%, and very large to nearly perfect correlations at all isoinertial loads. Consequently, this practical method of quantifying isoinertial resistance training could be useful for athletes to assist in the monitoring of training. However, caution should be applied when implementing this practical method of collecting kinetic outputs during research.

Very large to nearly perfect correlations were found at all isoinertial loads from the kMeter when compared with the gold standard criterion measure. Furthermore, the TEE of all outputs were below 10% which suggests these may be of use to practitioners for measuring performance when exercising. Additionally, due to the live repetition feedback of performance, athletes may be able to use these outcomes to enhance motivation and competitiveness when exercising (9, 10). However, it should be noted that the calculation of mean force and power output may not be precise enough to act as an alternative method of measuring these kinetic outputs for research purposes. This calls into question previous research (1) which has used this app to measure test-retest reliability across a range of exercises.

Although this study demonstrates the validity of both force and power when using this commonly implemented training device, it is not without limitations. First, this study only assessed force and power outputs during the harness squat. However, it should be noted that kinetic and kinematic information is calculated from rotation of the rotatory shaft when the tether is pulled. This information is subsequently transmitted to the app. Consequently, other commonly used exercises (e.g. bent over rows, Romanian deadlifts, and bicep curls (1)) should demonstrate similar levels of validity at the investigated loads. Second, due to the study design, it was not possible to detect whether systematic changes in validity occurred at different speeds when using the same isoinertial load. Nonetheless, practitioners should be aware that similar levels of TEE were observed across all isoinertial loads (i.e. TEE <10%). This suggests that despite having to overcome vastly different amounts of inertia (and consequently different amounts of velocity attained (5)), the validity of the app is maintained across different rotary shaft angular velocities.

In conclusion, the kMeter app that accompanies the kBox flywheel training device demonstrates satisfactory monitoring of mean force and power when exercising. These results can be of benefit for athletes and coaches alike and can be used to guide or monitor training. However, due to the moderate to large TEE, caution should be taken when utilising these kinetic measures for research purposes. Thus, this margin of error should be acknowledged as a limitation within future investigations. However, considering these findings, practitioners may wish to utilise the app in conjunction with other tools (e.g. subjective measures) for the monitoring of resistance training.

PRACTICAL APPLICATIONS

The kBox is commonly used as a resistance training tool. However, due to the unique nature of this device, monitoring of key training variables can be difficult. To circumnavigate this issue, the kMeter app can be used as it demonstrates satisfactory validity for the measurement of kinetic outcomes. Consequently, practitioners may wish to provide live feedback to athletes as they train or provide repetition and set information to athletes following exercise. Additionally, due to the smaller standardized bias and TEE, practitioners should consider using mean power output rather than force when monitoring and supplying feedback to athletes during training.

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Table 1. Agreement between criterion (force plate and high-speed camera setup) and practical measure (kMeter) of mean power and force[†].

Table 2. Intercept and slope values (with 90% confidence limits (CL)) and regression equations for comparisons between kBox kMeter and criterion measure.

Figure 1. Regression plots for agreement between the practical measure (kMeter) and criterion measure (force plate and high-speed camera setup).