CONSISTENCY OF PEAK FORCE OUTPUT WITHIN AND BETWEEN LOAD CONDITIONS USING AN INERTIAL FLYWHEEL RESISTANCE DEVICE

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INTRODUCTION: When training principles are properly manipulated within a training plan, the potential for favorable performance outcomes is improved. Overload, a fundamental training principle, involves providing an optimal stimulus that results in beneficial adaptations when consistently applied. Often, the stimulus must be increased in order to accommodate adaptation. This increase in stimuli forces the athlete to adapt to higher levels of a given performance characteristic (DeWeese, Hornsby, Stone, & Stone, 2015). An overload may be provided in the form of increased volume or frequency of training, but is most commonly prescribed as increasing absolute and relative intensities which in turn alters training volume (workload) (DeWeese et al., 2015). An overload of intensity may be provided with a variety of training methods across a macrocycle in order to build robust training adaptation and to provide variation.

An example of alternative means of providing resistance may be inertial flywheel resistance. In this method, a device provides resistance via inertial torque, the magnitude of which is a function of the radius, mass, and angular acceleration of the disc (Chiu & Salem, 2006). A greater radius and mass of the resistance or greater angular acceleration (via increased force production) will result in greater inertial torques from the device. Therefore, the magnitude of the resistance is provided partially by the device (i.e. size and mass), but also due in part to the previous repetition's force output (and subsequent acceleration) by the individual (Chiu & Salem, 2006). Due to the interplay between device and lifter-created resistance, an absolute (device) or relative (lifter) overload of resistance possibly may apply. Although research exists regarding the use of flywheel resistance (Greenwood, Morrissey, Rutherford, & Narici, 2007; Norrbrand, Pozzo, & Tesch, 2010), no studies to the authors' knowledge have specifically examined the consistency of the provided resistance across multiple loads within an inertial flywheel device.

When providing an overload stimulus using an inertial flywheel resistance device, practitioners must consider kinetic variables and outputs within and across load conditions before prescribing training overload using the devices. However, such progressive loading has not been studied to this point. Therefore, the purpose of the study was to determine within and between load-condition changes in peak force using an inertial flywheel device.

METHODS: Ten volunteers (9 males and 1 female, body mass = 87.43 $\pm$ 17.42kg) agreed to participate in the study. All participants were physically active and had no current injuries. Participants signed written informed consent approved by the University's Institutional Review Board.

To assess the kinetic responses to various intensities using an inertial flywheel, participants completed two testing sessions. The first session included familiarization to the protocol and was identical to the second (experimental) protocol. The protocol consisted of 2 sets of 13 repetitions at three load conditions: load 1 (0.010 kgm^2), load 2 (0.025 kgm^2), and load 3 (0.050 kgm^2) on an inertial flywheel device (Exxentric, Sweden). The first 3 repetitions of each set were used to create momentum prior to the working repetitions. Sets were completed in the order of lowest inertia to the highest. Each set was separated by two minutes of rest, with three minutes of rest prescribed when inertia was changed. All participants wore standardized footwear (Supernova, Adidas, Germany) to eliminate footwear as a confounding factor for force output.

Force data were collected using dual 2-Axis force platforms (Pasco, Roseville, CA, USA) connected to an interface at a sampling frequency of 500 Hz. Participants placed one foot on the center of each force platform, which were marked with tape for consistency (Sato & Heise, 2012). Force data were collected with Capstone software (Pasco, Roseville, CA, USA) and analyzed using Microsoft Excel™ 2010 (Version 2010, Redmond, WA, USA). Squat repetitions two through nine were used for analysis (not including the initial 3 repetitions). The first and last repetitions were excluded from analysis to account for consistency of effort between subjects. Descriptive statistics (mean, standard deviation, coefficient of variation) were calculated for peak force at each load condition. Intra-class correlations were also calculated to assess the repetition-to-repetition (rep-to-rep) reliability of the force data. Percent changes of peak force from rep-to-rep and between loading conditions were determined to further examine within set variation.

RESULTS: Repetition-to-repetition peak force demonstrated very strong reliability at all load conditions (ICC = 0.96 – 0.99). Mean, standard deviation (SD), and coefficient of variation (CV) for each repetition at each load condition are displayed in Table 1. Peak force percent change from the initial repetition increased on average in the later repetitions (Table 2), although the heaviest resistance represented the lowest amount of rep-to-rep change in peak force. The moderate resistance condition resulted in a 14.0% increased peak force and heavy resistance increased peak force by 22.4% compared to the low resistance condition.

Table 1. Peak Force Mean, SD, CV at each repetition, load condition

		Repetition							
Resistance		2	3	4	5	6	7	8	9
Load 1	Mean	1582.2	1600.8	1630.5	1640.3	1674.6	1674.5	1672.3	1656.6
	SD	310.3	332.4	335.2	360.0	378.8	362.6	371.0	359.9
	CV (%)	19.6	20.8	20.6	21.9	22.6	21.7	22.2	21.7
Load 2	Mean	1820.0	1819.9	1879.3	1855.3	1838.1	1865.5	1977.4	1914.7
	SD	486.0	414.9	452.5	407.6	398.6	399.7	498.6	447.4
	CV (%)	26.7	22.8	24.1	22.0	21.7	21.4	25.2	23.4
Load 3	Mean	1996.2	1978.1	1990.2	2040.4	1988.4	2047.7	2035.4	1993.5
	SD	529.9	488.7	524.4	549.8	535.7	559.6	548.7	543.5
	CV (%)	26.5	24.7	26.4	26.9	26.9	27.3	27.0	27.3

*SD = standard deviation, CV = coefficient of variation

Table 2. Peak Force Changes Between Load Conditions

Resistance	Average	SD	CV (%)	Percent Change vs. Low Resistance (%)
Low	1641.5	337.6	20.6	-
Moderate	1871.3	422.8	22.6	14.0
Heavy	2008.8	511.8	25.5	22.4

*SD = standard deviation, CV = coefficient of variation

DISCUSSION: The purpose of the study was to determine within and between load-condition changes in peak force using an inertial flywheel device. Force data were observed to have very strong rep-to-rep reliability at each load condition (ICC = 0.98 – 0.99). Consistency of force output is a key component in understanding the practical use of tools in an accurate manner such as inertial flywheel devices. If force output were inconsistent, loading would not be stable, therefore affecting the effort needed to complete the task. The high degree of consistency observed in the experiment indicate that if an appropriate level of overload is consistently achieved using the device, favorable training adaptations are possible. However, it is still unclear what manner of adaptation the device may elicit through training. Additionally, high between-subject variation (CV $\geq$ 19.6%) coupled with the high degree of reliability indicate that subjects may produce differing force outputs for a given load based on body mass, strength, or technical proficiency. The inconsistency observed between subjects may suggest an individual's force output will influence the resistance from the device.

Further analysis of rep-to-rep variability in force output indicate small percent changes within all load conditions. Greater changes were observed at later repetitions within each load condition, demonstrated by several percent changes surpassing 5%. This is possibly due to increased comfort in performing the movement using flywheel resistance as each set continued or due to local fatigue requiring more efficient allocation of force production. Although larger changes were observed in later repetitions, the magnitude of these changes seem trivial especially when considering the high rep-to-rep consistency.

The high rep-to-rep consistency of force output across multiple load conditions using an inertial flywheel device indicate the reliability of each load for providing the consistent resistance. Additionally, increasing magnitude of change when increasing the resistance from load 1 to load 2 (14.0% increase) and from load 1 to load 3 (22.4% increase) indicate that the flywheel resistance has the potential to provide an overload within the device. It is unclear if this within-device overload would be sufficient for individuals of higher strength levels. However, subjects creating more acceleration of the flywheel through increased force production may create greater resistances thus providing an overload. The results of this study indicated high reliability of force output within sets at a given load and displayed an increase in force production with increase in flywheel resistance. These results provide basis for further investigation into the usefulness of the inertial flywheel device in enhancing athletic performance. More research is warranted to determine how flywheel resistance devices relate to more traditional resistance training, and to overall training adaptation.

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