NUMBER OF WARM-UP REPETITIONS INFLUENCES BARBELL VELOCITY AT ONE-REPETITION MAXIMUM

John P. Wagle[1], Kevin M. Carroll[1]

[1]East Tennessee State University, Department of Exercise and Sport Science, Johnson City, TN, USA

INTRODUCTION: Executing a warm-up prior to performance has been shown to enhance subsequent performance (Sotiropoulos et al., 2010) and reduce the risk of injury (Safran et al., 1988). Unfortunately, most strategies in performance preparation are driven by the preference of the coach and not evidence-based practice (Safran et al., 1988). Inadequate warm-up protocols may not only impact the safety of the athlete, but also the subsequent performance, especially when exercise intensity is near maximal (Bergh & Ekblom, 1979). In maximal or high intensity activities, such as one-repetition maximum (1RM) testing, adequate warm-up prescription is necessary. Unfortunately, a universally accepted protocol has not been established.

Despite the lack of a widely accepted warm-up procedure, 1RM testing is a frequently used means of assessing maximal strength in practical setting. Evaluating maximal strength is of great value to coaches, as it is associated with sprint and jump performance, and likely transfers to a wide range of sporting events (Wisløff et al., 2004). Due to the potential implications for performance, accurate maximal strength measurements are required in prescribing appropriate training loads and monitoring progress. Recently, sport technology has become a popular way to collect quantitative data from a maximal test such as 1RM to better prescribe training loads. Such technology provides a means of assessing the accuracy of 1RM testing through the collection of mean concentric barbell velocity (Jidovtseff et al., 2011; Jovanovic & Flanagan, 2014). Due to the consistency of velocity at 1RM (V1RM) in squatting, measuring mean concentric velocity may provide a method to assess proximity to true 1RM during a test (Izquierdo et al., 2006; Sánchez-Medina & González-Badillo, 2010).

Assessment of proximity to 1RM may allow coaches to objectively examine their testing procedures, including the specifics of the warm-up. Currently no research has examined the effects that number of warm-up repetitions and resultant bar velocities at maximum intensity. Therefore, the purpose of this study was to evaluate the influence that number of warm-up repetitions had on velocity at 1RM during maximal strength testing in the back squat.

METHODS: Twenty Division I men's basketball student-athletes (age = 20.65 ± 1.39 years, height = 197.61 ± 7.44 cm, body mass = 94.62 ± 7.54 kg, squat 1RM = 151.95 ± 29.36 kg) participated in the study as part of an ongoing athlete monitoring program.

Prior to beginning testing, subjects completed a standardized general warm-up, followed by 10 bodyweight squats and 5 bodyweight squat jumps. To assess squat 1RM, a modified version of a previously established method was used with the additional instruction of completing each repetition with the intent of maximal concentric velocity (McBride, Triplett-McBride, Davie, & Newton, 2002). Back squats were completed using a standard free weight squat rack and a 20-kg barbell. All repetitions were executed to a target set at approximately 90-degrees of knee flexion. Load and mean concentric barbell velocity were recorded for each attempt. Mean concentric barbell velocity was collected using commercially available GymAware units (Kinetic Performance, Canberra ACT, Australia).

A linear regression analysis assessed the relationship between the dependent variable, velocity at 1RM (V1RM), and the independent variable, number of warm-up repetitions (WUREPS) using Microsoft Excel™ 2010 (Version 2010, Redmond, WA, USA). Analysis was evaluated for significance at an alpha level of $p \leq 0.05$. These data were assessed for outliers using SPSS (Version 22.0.0, Armonk, NY: IBM Corp).

RESULTS: Velocity data based on number of warm-up repetitions for each athlete are displayed along with group means in Figure 1. A significant regression model was found ($F(1,18) = 17.665$, $p < 0.01$) indicating that WUREPS (mean = 6.60, SD = 1.353) explained 49.5% of the variance in V1RM (mean = 0.375, SD = 0.124).

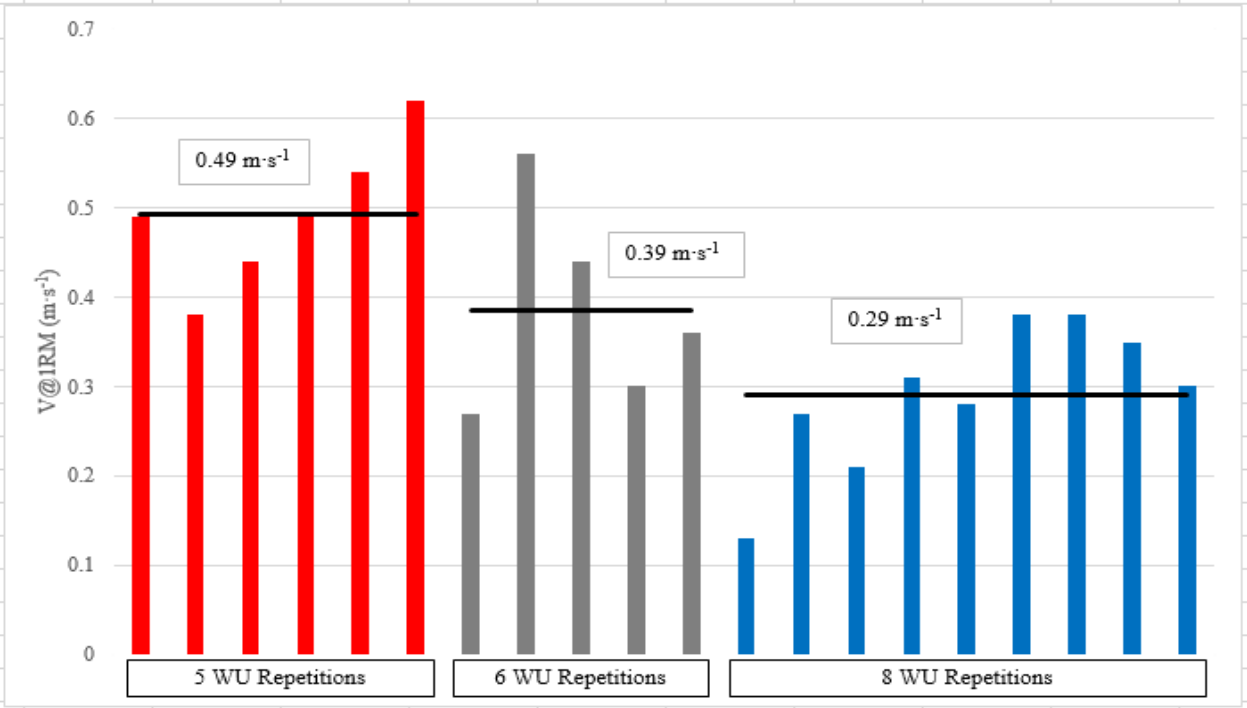

Figure 2. V1RM for each athlete grouped by number of warm-up repetitions performed. Horizontal bars indicate group averages.

DISCUSSION: The main finding of the current study indicated that a significant portion of the variance in V1RM was explained by WUREPS. To our knowledge, this was the first study to examine such an influence. Due to the consistency of velocity at the terminal repetition seen across a variety of intensity prescriptions with back squats, values of V1RM can be potentially deduced for higher intensity prescriptions (Izquierdo et al., 2006). Theoretically, if the V1RM value is significantly greater than these observed values from Izquierdo and associates (2006), it can be inferred that the 1RM test did not evaluate maximal strength accurately. Coaches implementing maximal strength testing may then consider V1RM as an estimate of the accuracy of the protocol.

Many factors influence the accuracy of 1RM protocols such as effort level, strength level, or technical proficiency (Zourdos et al., 2016). Our results indicate that one controllable aspect of the testing protocol that directly impacts V1RM is the number of warm-up repetitions, which may influence the accuracy of the test. Coaches should design 1RM testing procedures that

allow for a higher number of warm-up repetitions. This will require balancing preparedness and fatigue, however, as too many attempts may be detrimental to performance (Linnamo et al., 1998). If more optimal warm-up procedures are programmed, 1RM testing may provide coaches more accurate data when evaluating an athlete's maximal strength abilities.

It should be noted that the current study was performed in a practical environment, and though this provides a high level of ecological validity, subsequent studies should seek to provide more control and explore greater deviations in number of warm-up repetitions to determine the contribution that number of warm-up repetitions has on V1RM, and thus, theoretically, the accuracy of 1RM testing outcomes.

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