

# Changes in joint kinematics and kinetics through the implementation of inter-repetition rest protocols in snatch training

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## Abstract

**Background and Study Aim** Inter-repetition rest pertains to a short period of rest between repetitions during strength training. Manipulating inter-repetition rest may influence fatigue accumulation, manifesting alteration in lifting mechanics. This study aimed to examine the effects of different inter-repetition rest protocols on joint velocity and ground reaction force during snatch exercise.

**Material and Methods** Fifteen male (n=15) athletes participated in this study (age = 23.0 ± 2.31 years; body weight = 65.32 ± 1.37 kg; height = 168.80 ± 5.64 cm; snatch one repetition maximum (1RM)/bodyweight = 0.78 ± 0.12), performing three sets of 5 repetitions at 85% 1 Repetition Maximum snatch with 10, 30, or 50 seconds of inter-repetition rest implemented randomly across three sessions. Ankle, knee, and hip kinematics and ground reaction force in the three protocols were used for comparison. The participants visited the exercise science laboratory for four sessions between 0800-1700 hrs. These sessions were separated by 72 hours.

**Results** One-way repeated measure analysis of variances (ANOVA) showed a significant effect of inter-repetition rest on the maintenance of kinematic and kinetic variables. The ground reaction force for 10 seconds inter-repetition rest protocol showed a significant drop in force output across repetition (p = .037, p < 0.05).

**Conclusions** The utilization of inter-repetition rest in snatch exercise may reduce neuromuscular fatigue across repetitions, maintaining consistent performance output. Specifically, the 50 second inter-repetition rest protocol reduced the negative effect of neuromuscular fatigue in the kinematic and kinetic variables during snatch exercise.

**Keywords:** power, recovery, exercise, Olympic weightlifting, maximal strength, recovery

## Introduction

Strength and conditioning coaches use a variety of resistance training [1] schemes for development of power, a physiological characteristic crucial to athletic performance. Among which is the utility of weightlifting exercises in RT programs. The mechanical stimuli from weightlifting exercises are believed to aid in enhancing neuromuscular adaptations related to power [2, 3].

Power, force output and velocity have been demonstrated to decrease with each repetition during high-intensity RT [4-8]. For example, Izquierdo et al. [9] posted decreased velocity across repetitions to failure in squat and bench press exercises. Duffey and Challis [10] also showed significant reduction in mean and peak velocity across repetition to failure during bench press. The attenuation in force and velocity output across repetitions are mainly linked to muscular fatigue [11, 12]. Thus, the employment of strategies to minimize fatigue during exercise repetitions may be beneficial to aid in training goals.

Recently, the inter-repetition rest (IRR) was suggested to reduce the effect of fatigue in RT.

A study by Haff et al., [13] demonstrated higher clean pull barbell velocity with IRR compared to traditional set protocol that used no rest in between repetitions. Lawton et al. [7] also exhibited greater power output per repetition obtained during a bench press exercise from IRR protocols compared to the continuous repetition protocols. Garcia Ramos et al. [4] posted more half squat repetitions with IRR than squat under continuous repetitions. Similarly, Mora-Custodio et al. [14] showed lower incidence of fatigue, percentage velocity loss, and lactate concentration during full squat with IRR than continuous repetitions. These studies suggest that employment of IRR may contribute to increased exercise efficiency.

While the previous studies involving IRR provide insight on kinematic and kinetic variables across repetitions, majority were executed using a single-set protocol. The effect of IRR across repetitions, involving multiple sets, remains unknown. Such information may be crucial for implementing exercises to aid in power development. Thus, this study aimed to examine the effects of IRR on lower body kinematic and kinetic parameters of snatch across multiple sets.

## Materials and Methods

### Participants

Fifteen active male athletes (age:  $23.0 \pm 2.31$  years, weight:  $65.32 \pm 1.37$  kg, height:  $168.80 \pm 5.64$  cm, 1RM of snatch relative to body mass:  $0.78 \pm 0.12$  kg. kg<sup>-1</sup>) volunteered to participate in this study. The sample size was based on a previous study with a similar design [5, 15]. The inclusion criteria were: (a) ability to lift at least 50% of their body weight during the snatch exercise; (b) at least six months of experience in a snatch training exercise; and, (c) non-use of drugs or dietary supplements that could affect physical performance. All participants were informed of the benefits and risks of the investigation before signing the informed consent. The experimental protocol adhered to the principles of the 1975 Helsinki Declaration and was approved by the ethical committee of Sultan Idris Education University Institutional Ethical Review Board.

### Procedure

The participants visited the exercise science laboratory for four sessions between 0800-1700 hrs. These sessions were separated by 72 hours. To avoid diurnal variations, participants visited the facility at the same time across four sessions. In session one, anthropometrics (height and weight), equipment familiarization, and one-repetition maximum (1 RM) were administered. The 1RM testing was performed in the manner described by Baechle and Earle [9], facilitated by a certified strength and conditioning specialist. Sessions two to four were interspersed by 72 hours, with participants performing a general warm-up of five-minute jogging and five-minute stationary cycling. Participants then continued with dynamic upper body and lower body stretching using elastic bands, followed by five repetitions of snatch at 20-kg load. A five-minute active rest was implemented after warm-up. This was succeeded by three sets of five repetitions of snatch at 85% 1 RM, with a five-minute rest in between sets. The three protocols in this study included the 10s, 30s and 50s intervals, implemented as the rest duration in-between each snatch repetition.

The kinematic data of ankle, knee, and hip joint were captured at 100 Hz using 3D Vicon motion capture system with 6 Vicon T-10s cameras (Vicon Motion Systems Ltd UK, West Way, Oxford). The markers were placed on the left and right anterior superior iliac spine, left and right lateral thigh, left and right lateral epicondyle of the knee, left and right medial epicondyle of the knee, left and right lateral tibia, left and right lateral malleolus, left and right medial malleolus, left and right second metatarsal, and left and right heel. Only the data taken from the right leg were analyzed to be presented in this study. The first pull and second pull phases of snatch were analyzed in this study. The first pull refers to the barbell lift-off until the

maximum knee extension, while the second pull occurs from the first maximum knee flexion until the second maximum knee extension [16]. The data is processed using VICON Polygon (Vicon Motion Systems Ltd UK, West Way, Oxford), filtered using 4th order Butterworth filter with cut-off frequency at 6 Hz [17, 18].

The vertical ground reaction force (GRF) of each snatch repetition was recorded using an AMTI force plate (Advanced Mechanical Technology, Inc, Watertown, MA) at 1000 Hz. The GRF was filtered using the 4th order Butterworth filter with a cut-off frequency of 25 Hz [17, 18]. The peak GRF at each snatch repetition was utilized for analysis.

### Statistical analysis

The mean values of each repetition from the three sets across IRRs were utilized for analyses. A 3 (IRR) x 5 (repetition) repeated measure analysis of variance (ANOVA) was used to determine any significant main effect and interaction. The partial eta squared (partial  $\eta^2$ ) was utilized for estimating effect size. The Greenhouse-Geisser correction was employed for any violation on sphericity. Additionally, the Bonferroni post-hoc was utilized to determine any significant pairwise comparison. Statistical analysis was conducted in a commercial statistical package, SPSS version 25 (SPSS Inc., Chicago, IL.), with significance set at 0.05 level.

## Results

### First Pull

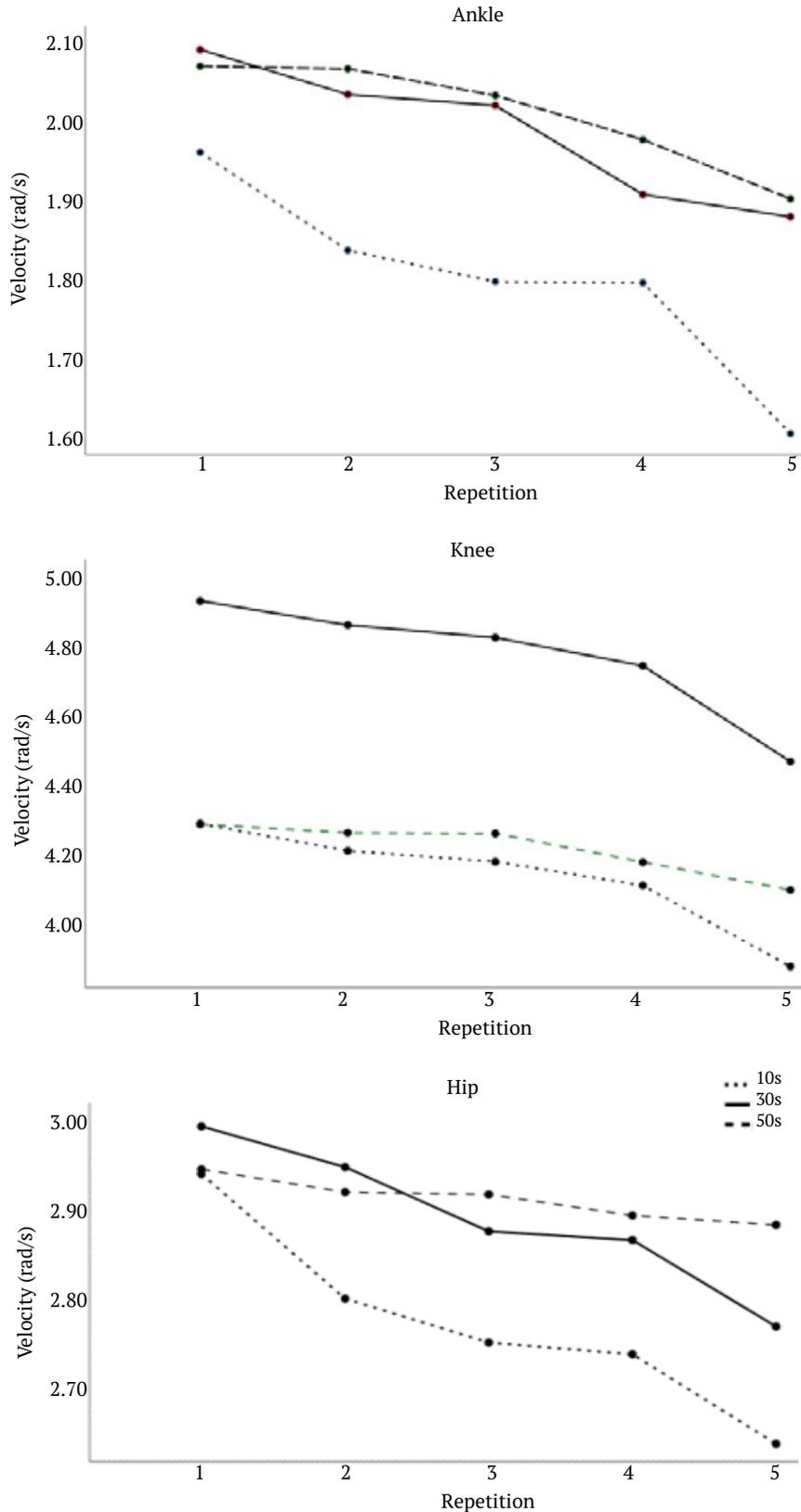
The 2 x 5 repeated measures ANOVA revealed non-significant main effect of intervention on ankle joint velocity,  $F(1.401, 19.62) = 2.268$ ,  $p = 0.122$ , partial  $\eta^2 = 0.139$ . There was a significant main effect of repetition on ankle joint velocity,  $F(4, 56) = 3.661$ ,  $p = 0.010$ , partial  $\eta^2 = 0.207$ . Bonferroni post-hoc posted significant reduction in angular velocity between 1<sup>st</sup> (mean = 1.969 rad/s) repetition and 5<sup>th</sup> repetition (mean = 1.617 rad/s) of the 10 s IRR ( $p = 0.023$ ). The interaction in intervention and repetition on ankle joint velocity was not significant,  $F(8, 112) = 0.288$ ,  $p = 0.969$ , partial  $\eta^2 = 0.207$ .

The main effect of intervention on knee joint velocity was not significant,  $F(2,28) = 0.830$ ,  $p = 0.447$ , partial  $\eta^2 = 0.056$ . The main effect of repetition on knee joint velocity was significant,  $F(4, 56) = 4.895$ ,  $p = 0.002$ , partial  $\eta^2 = 0.259$ , with post-hoc demonstrating knee joint velocity difference between 1<sup>st</sup> repetition (mean = 4.315 rad/s) and 5<sup>th</sup> repetition (3.913 rad/s) of the 10 s IRR at  $p = 0.003$ . There was no significant interaction between intervention and repetition on knee joint velocity,  $F(8, 112) = 0.237$ ,  $p = 0.983$ , partial  $\eta^2 = 0.017$ .

Non-main effect of intervention was found in hip joint velocity,  $F(2,28) = 0.447$ ,  $p = 0.644$ , partial  $\eta^2 = 0.031$ . There was a significant main effect of repetition on hip joint velocity,  $F(4, 56) = 3.536$ ,

$p = 0.012$ , partial  $\eta^2 = 0.202$ . Pairwise comparison showed significant difference between the 1<sup>st</sup> repetition (mean = 2.939 rad/s) and 5<sup>th</sup> repetition (mean = 2.632 rad/s) of the 10 s IRR.. There was no significant interaction between intervention and

repetition on hip joint velocity,  $F(8, 112) = 0.368$ ,  $p = 0.935$ , partial  $\eta^2 = 0.026$ . Figure 1 shows the peak ankle, knee, and hip joint kinematics during first pull of the snatch across repetitions.



**Figure 1.** Peak Joint Kinematics at Snatch First Pull from Various Inter-repetition Rest Intervals

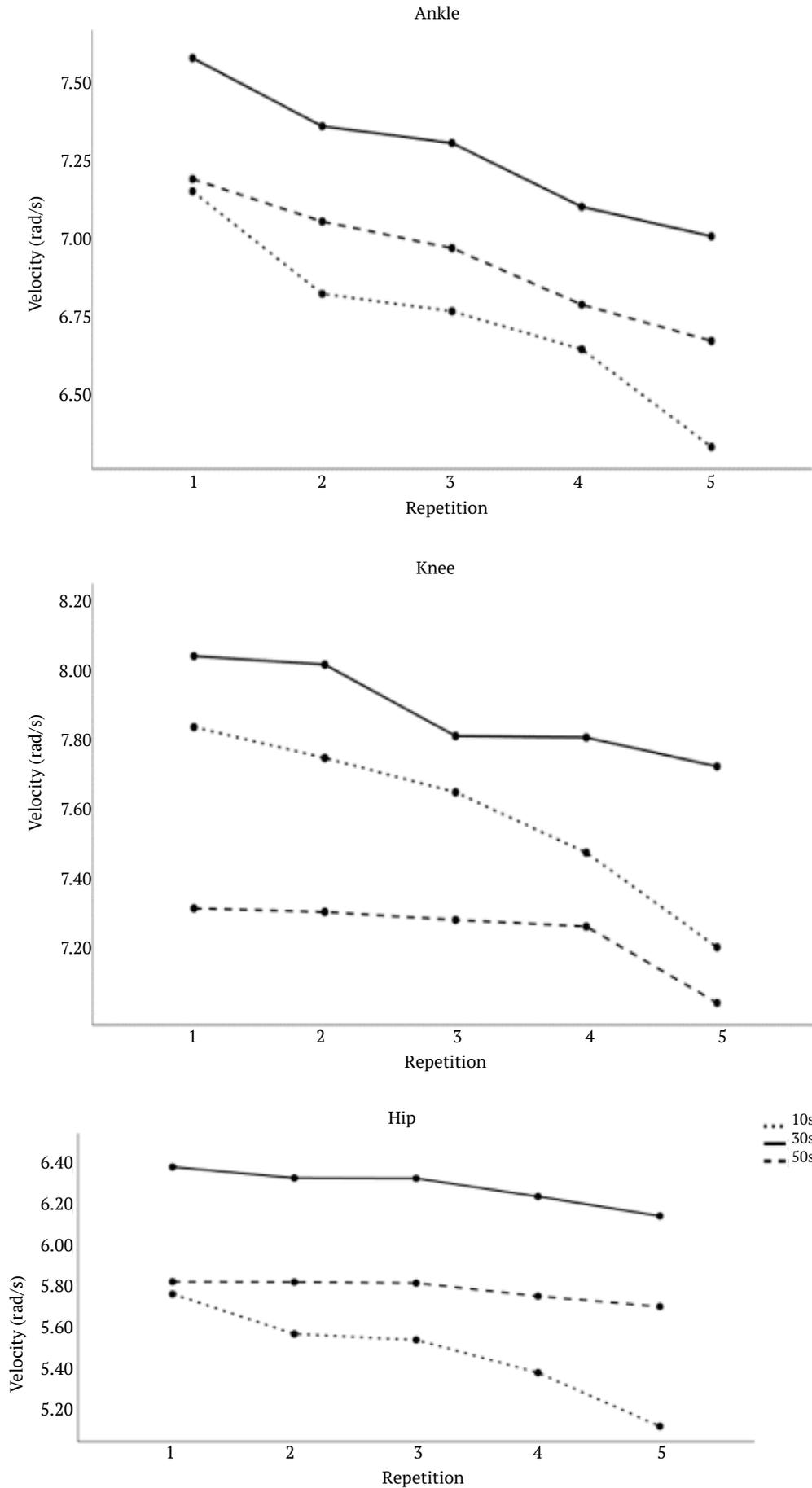
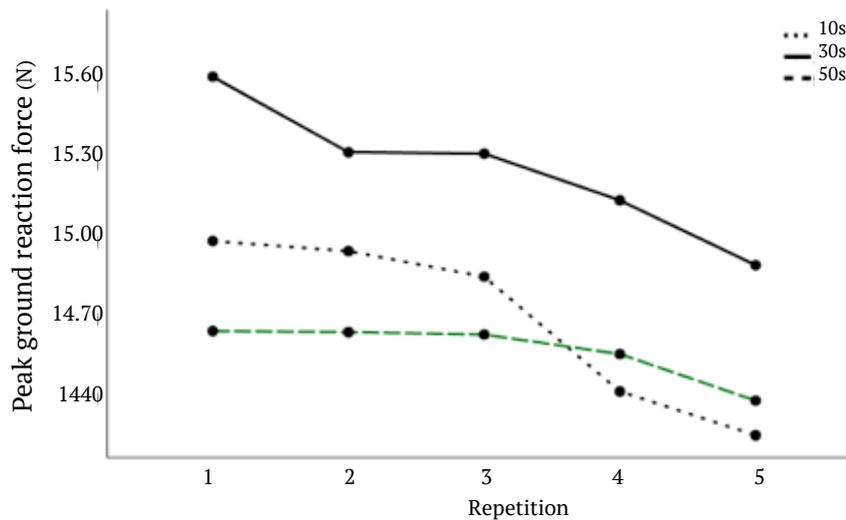


Figure 2. Peak Joint Kinematics at Snatch Second Pull from Various Inter-repetition Rest Intervals



**Figure 3.** Peak GRF at each repetition from different IRRs.

### Second Pull

Non-significant main effect of intervention on ankle joint velocity was identified,  $F(2,28) = 0.216$ ,  $p = 0.807$ , partial  $\eta^2 = 0.015$ . There was a significant main effect of repetition on ankle joint velocity,  $F(4, 56) = 4.912$ ,  $p = 0.002$ , partial  $\eta^2 = 0.260$ , and post-hoc exhibited ankle joint velocity difference between 1<sup>st</sup> repetition (mean = 7.167 rad/s) and 5<sup>th</sup> repetition (6.373 rad/s) of the 10 s IRR ( $p = 0.013$ ). No significant interaction between intervention and repetition was found on knee joint velocity,  $F(8, 112) = 0.101$ ,  $p = 0.999$ , partial  $\eta^2 = 0.007$ .

There was no significant effect of intervention was found on knee joint velocity,  $F(2,28) = 0.155$ ,  $p = 0.857$ , partial  $\eta^2 = 0.011$ . There was also no significant main effect of repetition on knee joint velocity,  $F(4, 56) = 2.283$ ,  $p = 0.072$ , partial  $\eta^2 = 0.140$ . The interaction of intervention and repetition on knee joint velocity was non-significant,  $F(8, 112) = 0.204$ ,  $p = 0.990$ , partial  $\eta^2 = 0.014$ .

The main effect of intervention on hip joint velocity was not significant,  $F(2,28) = 1.969$ ,  $p = 0.158$ , partial  $\eta^2 = 0.123$ . There was a significant main effect of repetition on hip joint velocity,  $F(4, 56) = 3.766$ ,  $p = 0.009$ , partial  $\eta^2 = 0.212$ , with pairwise comparison revealing significant difference between the 1<sup>st</sup> repetition (mean = 5.768 rad/s) and 5<sup>th</sup> repetition (mean = 5.102 rad/s) of the 10 s IRR.. No significant intervention and repetition interaction was seen on hip joint velocity,  $F(3.757, 52.60) = 1.192$ ,  $p = 0.310$ , partial  $\eta^2 = 0.078$ . Figure 2 depicts the peak ankle, knee, and hip joint kinematics during the second pull of the snatch across repetitions.

### Ground Reaction Force

There was no significant main effect of group on peak GRF,  $F(1.027, 14,38) = 0.649$ ,  $p = 0.530$ , partial  $\eta^2 = 0.044$ . On the other hand, the main effect of repetition was significantly different,  $F(4,$

56) = 3.456,  $p = 0.014$ , partial  $\eta^2 = 0.198$ . Post-hoc revealed significant reduction on peak GRF between 1<sup>st</sup> repetition (mean = 1500 N) and 5<sup>th</sup> repetition (mean = 1425 N) of the 10 s IRR at  $p = 0.045$ . No interaction effect was found between group and repetition on peak GRF,  $F(8, 112) = 0.502$ ,  $p = 0.853$ , partial  $\eta^2 = 0.035$ . Figure 3 shows the peak GRF at each repetition from different IRRs.

### Discussion

The purpose of this study was to examine the kinematics of snatch exercise from different IRRs. Specifically, the researchers investigated the ankle, knee, and hip joint kinematics from different IRRs during snatch exercise. Results revealed no significant snatch first pull joint kinematic differences between the 10s, 30s, and 50s IRRs. Similarly, there was also no significant snatch second pull joint kinematic differences between the 10s, 30s, and 50s IRRs. The secondary purpose of this study was to examine the snatch ground reaction force from the 10s, 30s, and 50s. It was found that no significant difference existed in the GRF during the 10s, 30s, and 50s.

In this study, no kinematic differences were observed from different IRRs. The snatch first pull plays a critical aspect for the generation of momentum in second pull. Further, the 1st pull sets the biomechanical stage for proper execution of the entire lift, needed for efficient and safe movement pattern [19]. Although no group differences were found, it should be noted that the 10s demonstrated the most notable trend in reduction of ankle, knee, and hip joint kinematics compared to the 30s and 50s IRR protocols. It may be possible that the 10s rest was not sufficient to facilitate replenishment of energy stores, that may help reduce fatigue from executing snatch repetitions [20, 21]. This is partially supported by previous studies that

showed reduction in kinematic parameters from multiple exercise repetitions performed from short-duration IRRs [7, 15, 22-25]. While non-kinematic differences in snatch first pull were identified in this study, it appears that application of 10s IRR may contribute to a more pronounced attenuation in kinematics, that resulted from incomplete energy repletion. Thus, caution must be observed when implementing 10s IRR for snatch repetitions, as this may potentially reduce exercise efficiency and increase faulty movement patterns.

No second pull kinematic differences across IRRs were also demonstrated in this study. The second pull is considered as the most explosive phase of snatch, facilitating the upward acceleration of the bar [19]. While no group differences were identified, the 10s IRR displayed the greatest trend in reduction of ankle and hip kinematics compared to 30s and 50s protocols. It may seem that the snatch performed with 10s IRR exhibited more decrement trend on kinematic output which showed kinematic reduction across repetitions. The slower second pull kinematics in 10s IRR may have also resulted from the slower first pull kinematic output. Large reduction in velocity during the second pull movement may result to movement imbalance towards catch phase of snatch [26]. Thus, it seems that facilitation of longer IRR may help maintain velocity in snatch exercise repetitions, leading to favorable kinematic adaptations.

This study also posted no kinetic differences across IRRs. However, it should be noted 50s IRR demonstrated greater preservation of GRF across repetitions. The longer rest interval may have facilitated the partial recovery and reversal of fatigue [7, 13, 27]. Specifically, the longer rest allowed resynthesis of phosphocreatine, which is important in execution of explosive actions [28]. The results of this study somehow coincide with previous

studies indicating the maintenance of kinetics from longer IRRs [7, 8, 13, 22, 23]. For example, Lawton, Cronin [7] demonstrated greater power output (21-25%) during bench press with longer IRR when compared with the continuous set protocols [7]. The longer IRR reduce neuromuscular fatigue [29], and may help maintain kinetic properties in exercise performance. Therefore, it shows that employment of 50s IRR may be helpful in maintaining similar force output during snatch repetitions.

While this study provided novel information on the contribution of IRR on phase kinematics of snatch, limitations are acknowledged. First, generalization of findings should be avoided as the results are only applicable to the participants of this study. Also, the study presented high inter-subject variability, which may have affected the results of this study. Lastly, only kinetic and kinematic parameters were evaluated from IRRs. Inclusion of psychological and physiological parameters in future studies may help explain the extent of IRRs in performance settings.

## Conclusions

Implementation of IRR in snatch exercise may help in exercise, facilitating better adaptations in lower body kinematics and kinetics. In this study, no first pull kinematic differences were found after performing three sets of snatch using the 10s, 30s, 50s IRRs. Similarly, no second pull kinematic differences across IRRs were also identified. Lastly, kinetic non-differences were found across IRRs. More studies are needed to elucidate information on the phase kinematic contribution of IRR in snatch exercise.

## Conflicts of Interest

The authors declare no conflicts of interest.

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