

## Diurnal Variation in Stretch Shortening Cycle and Non-Stretch Shortening Cycle Jumping Performance

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This study assessed the diurnal variations, as well as the subjects' perceptions of how time of day affects their jumping performance. Eighteen subjects participated in testing sessions at 7 a.m., noon, and 5 p.m., on the same day. Subjects performed squat jumps (SJ) and countermovement jumps (CMJ) on a force platform with peak ground reaction force (GRF), jump height, and reactive strength index-modified (RSI<sub>mod</sub>) obtained for each jump. Diurnal differences for the CMJ were found for GRF ( $P = 0.048$ ). Diurnal differences for the SJ were found in RSI<sub>mod</sub> ( $P = 0.04$ ). Subjective assessment of jumping explosiveness was significantly different across time of day ( $P = 0.047$ ). Lower body power training such as plyometrics, may be more effective at mid day than early morning or late afternoon.

**KEY WORDS:** time of day, morningness, eveningness, plyometric, jump, power

**INTRODUCTION:** Knowing when an athlete performs at their peak may be useful in guiding the time of day during which they train. Research has assessed diurnal variations of training for a variety of parameters such as strength, anaerobic and aerobic capacity, and body temperature (Cappaert et al., 1999; Edwards et al., 2013; Lericollais et al., 2009; Lipkova et al., 2001; Racinais et al., 2005; Reilly & Bambacichi, 2003). Studies assessing diurnal variations have shown mixed results. Therefore, questions remain regarding diurnal variations during physical tasks.

A number of studies found no diurnal differences in a variety of physical variables such as anaerobic muscular power (Blonc et al., 2010), bench press strength (Lipkova et al., 2001), and vertical jump tests (Racinais et al., 2004). On the other hand, several studies found diurnal differences during the performance of strength tasks such as grip and isometric knee extension strength (Edwards et al., 2013), 60 second Wingate testing (Lericollais et al., 2009), and cycling power (Racinais et al., 2005). One study assessed vertical jumps and found some time of day differences in the take-off power (Lipkova et al., 2001). Many studies evaluating diurnal variations assess only morningness and eveningness (Edwards et al., 2013; Lericollais et al., 2009; Racinais et al., 2005), including those that used subjective self-assessment measure (Rossi et al., 1983).

The effect of diurnal variations on lower body power during stretch shortening and non-stretch shortening cycle jumping, and the influence of times of day other than morning and evening are not well understood. Therefore, the purpose of this study was to examine the role of diurnal variation on both stretch shortening cycle (SSC) and non-SSC jumping kinetic performance at three specific times throughout the day. This study also seeks to identify the subject's perceptions of how the time of day affected their performance.

**METHODS:** Eighteen subjects (age =  $19.94 \pm 1.73$  years) participated in this study. The study was approved by the institution's internal review board and subjects provided written informed consent.

Subjects were habituated to the test jumps prior to testing. Subjects then performed testing sessions at 7 a.m. (700 hours), noon (1200 hours), and 5 p.m. (1700 hours), on the same day. Subjects performed a standardized general and activity specific warm-up prior to testing. Subjects then performed 6 test jumps including 3 squat jumps (SJ) and 3 countermovement jumps (CMJ) on a force platform (BP6001200, Advanced Mechanical Technologies, Inc., Watertown, MA, USA) which was calibrated with known loads to the

voltage recorded prior to the testing session. Kinetic data were collected at 1000 Hz, real time displayed and saved with the use of computer software (BioAnalysis 3.1, Advanced Mechanical Technologies, Inc., Watertown, MA, USA) for later analysis. All values were averaged for the three trials for each exercise.

Dependent variables obtained for each jump included peak ground reaction force (GRF), jump height (JH), and reactive strength index modified ( $RSI_{mod}$ ). The  $RSI_{mod}$  was calculated from values from the force platform as jump height divided by time to take off. The SJ and CMJ were included to assess both SSC and non SSC jumps, respectively. These dependent variables were calculated from the force time records of each exercise consistent with methods previously used (Ebben & Petushek, 2010; Jensen & Ebben, 2007; Moir, 2008; Raynor & Seng, 1997). After each series of jumps, subjects were asked to give a subjective assessment of how explosive they felt while performing their jumps. After the last session, subjects were asked to complete a Horne-Östberg Morning-Eveningness Questionnaire (MEQ) to determine their subjective diurnal preferences.

The statistical analyses were undertaken with SPSS 20.0 using a repeated measures ANOVA with repeated measures for the time of day. Bonferonni adjusted pairwise comparisons were used to identify the specific differences in the dependent variables. Reliability was estimated using a two-way mixed Intra-Class Correlation and repeated measures ANOVA to test differences between trials. Significance was set at  $p \leq 0.05$  and if differences were found between trials follow-up pair-wise comparisons were performed with Bonferonni's correction. Assumptions for linearity of statistics were tested and met. An *a priori* alpha level of  $P \leq 0.05$  was used.

**RESULTS:** Diurnal differences for the CMJ were found for GRF ( $P \leq 0.05$ ), with the 1200 hours performance exceeding the 700 hours performance by 3.2% ( $P \leq 0.05$ ). Diurnal differences for the SJ were found in  $RSI_{mod}$  ( $P \leq 0.05$ ) with 1200 performances exceeding the 1700 hours performance by 5.6% ( $P \leq 0.05$ ). No other significant time of day differences ( $P > 0.05$ ) were found for any variables for the CMJ or SJ. Subjective assessment of jumping explosiveness was significantly different across time of day ( $P \leq 0.05$ ). Post hoc analysis showed that subjects felt more explosive at 1200 hours than at 700 hours ( $P \leq 0.05$ ). Intraclass correlation coefficients assessing the trial to trial reliability ranged from 0.93 to 0.99 for the exercise conditions and dependent variables.

**DISCUSSION:** This is the first study to find that mid day lower body power performance exceeded that of morning, late afternoon performance for both SSC and non-SSC jumping. This study adds to the literature confirming the existence of diurnal variations in the performance of physical tasks (Edwards et al., 2013; Lericollais et al., 2009; Liplova et al., 2001; Racinais et al., 2005).

Results of the present study are in contrast to those studies that failed to find diurnal variations (Blonc et al., 2010; Racinais et al., 2004), and demonstrates that diurnal variations exist at times of day other than morning or evening (Edwards et al., 2013; Lericollais et al., 2009). Previous studies often demonstrated eveningness, when compared to morningness (Edwards et al., 2013; Lericollais et al., 2009), or found better late afternoon, compared to morning performance (Racinais et al., 2005). In contrast, the present study showed that performance was higher at 1200 hours than either 700 hours or 1700 hours, suggesting that mid day may be optimal.

These finding of time of day differences in performance in the present study are somewhat consistent with previous research that found diurnal variations in physical tasks other than jumping or lower body power, including handgrip strength, isokinetic leg strength and four measures of MVIC (Edwards et al., 2013), 60s Wingate testing (Lericollais et al., 2009), and maximum cycle sprints (Racinais et al., 2005).

Finally, this study also evaluated subject's self-perception of time of day preferences for physical activity using the MEQ. Subjects in the present study reported feeling more explosive at 1200 hours, which was consistent with some measures of improved performance at 1200 hours compared to 700 or 1700 hours. This finding is consistent with

previous research using MEQ which showed that testing diurnal variations subjectivity through the use of an MEQ was predictive of subject's chronotype (Rossi, 1983).

**CONCLUSION:** Results of this study show that jumping may be more effective at mid day rather than early morning or late afternoon. Additionally, athlete's subjective experiences of when they feel most optimal physically, should be considered, when scheduling plyometric training sessions.

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