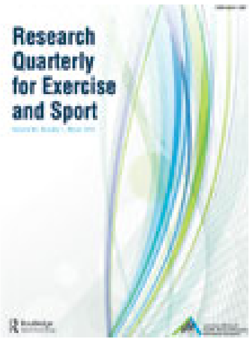

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Effects of Time-of-Day Training Preference on Resistance-Exercise Performance

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ABSTRACT

Purpose: The purpose of this study was to investigate how time-of-day training preference influences resistance-exercise performance. **Methods:** Resistance trained males (n = 12) were recruited for this study. In a crossover, counterbalanced design, participants completed two separate bench-press exercise trials at different times of day: (a) morning (AM; 8:00 hr) and (b) evening (PM; 16:00 hr). Participants answered a questionnaire on time-of-day training preference and completed a preferred (PREF) and nonpreferred (NON-PREF) time-of-day trial. For each trial, motivation was measured using a visual analog scale prior to exercise. Participants completed 2 sets × 2 repetitions at 75% 1-RM with maximum explosiveness separated by 5 min of rest. Mean barbell velocity was measured using a linear position transducer. Participants then completed 1 set × repetitions to failure (RTF) at 75% 1-RM. Rate of perceived exertion (RPE) was measured immediately following exercise. **Results:** Regardless of preference, velocity (p = .025; effect size (ES) = 0.43) was higher during the PM versus AM trial. However, there were no significant differences in velocity (p = .368; ES = 0.37) between PREF and NON-PREF time of day. There were no significant differences for repetitions between PREF and NON-PREF times (p = .902; ES = 0.03). Motivation was higher in the PREF time versus NON-PREF (p = .015; ES = 0.68). Furthermore, RPE was significantly lower during the PREF time of day (p = .048; 0.55). **Conclusions:** Despite higher barbell velocity collectively at PM times, time-of-training preference did not largely influence resistance-exercise performance, while motivation is higher and RPE is lower during preferred times.

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Bench press; morning; evening; velocity

Regular resistance training promotes increases in strength, muscular endurance, hypertrophy, and muscular power. Optimizing intensity, volume, and velocity of movement during resistance exercise may enhance adaptations. The time of day in which exercise is performed has been shown to influence power and velocity in multiple modes of anaerobic exercise (Bernard et al., 1997; Mora-Rodríguez et al., 2012). Moreover, diurnal exercise preference, it has been suggested, plays an important role in exercise behavior and training habituation (Hisler et al., 2016; Rae et al., 2015). However, much less is known concerning how time-of-day training preference influences resistance-exercise performance and may have important implications in adaptive responses to exercise.

Diurnal variations in exercise performance have been well documented in a variety of exercise modalities but findings have been inconsistent (Deschenes et al., 1998; Pallarés et al., 2014; Saygin et al., 2018; Zarrouk et al., 2012). Zarrouk et al. showed that peak power and total work during cycling sprints were significantly higher in evening times than in morning times (Zarrouk et al., 2012). Further supporting this, Pallares et al. showed bench-press strength and 25 m swimming time were higher later in the day than earlier in the day (Pallarés et al., 2014). However, others have reported that time of day has little to no impact on performance measures (Deschenes et al., 1998; Falgairette et al., 2003). Deschenes et al. found no differences in aerobic exercise performance with varying times of day despite fluctuations in plasma catecholamines and lactate with exercise (Deschenes et al., 1998). Falgairette et al. reported that regardless of exercise recovery duration, time of day did not influence peak power or total work during sprints (Falgairette et al., 2003). Thus, possible factors leading to diurnal changes in performance remain unclear, necessitating further investigation.

Preference of time of day for training has largely been studied in the context of exercise behavior and

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adherence (Hisler et al., 2016; Lastella et al., 2016). Hisler et al. found that individuals exercised more frequently during preferred times of day when measuring physical activity both objectively and subjectively (Hisler et al., 2016). Positive attitudes toward exercise are higher during preferred times of day for physical activity in adolescents (Schaal et al., 2010). Furthermore, affective responses to exercise accompanying intermittent fasting during Ramadan may be influenced by time-of-day preference (Chtourou et al., 2014). Evidence has shown that athletes tend to choose to participate in sports in which training occurs during their preferred time of day for exercise (Lastella et al., 2016). Less is known about how time-of-day training preference influences acute exercise performance and given that time of day influences exercise behavior, a greater understanding of these relationships may have important implications for adaptations with chronic exercise training.

Velocity and power of movement appear to be particularly vulnerable to diurnal fluctuations (Bernard et al., 1997; Mora-Rodríguez et al., 2012, 2015). Ballistic movement performance has been shown to be lower during morning times (López Samanes et al., 2017). Bernard et al. reported that jumping power and maximal anaerobic velocity were higher in the afternoon than in the morning (Bernard et al., 1997). Mora-Rodríguez et al. reported lower barbell velocity during back-squat and bench-press exercise during morning times compared with evening times (Mora-Rodríguez et al., 2012). Mean propulsive velocity during back-squat exercise at loads ≤ 75% 1-RM is also lower during the morning compared to evening (Mora-Rodríguez et al., 2015). A recent comprehensive meta-analysis of how time of day influences resistance-training adaptations suggested that while evening times lead to better acute performance, the differences in long-term training benefits between morning and evening regimens is trivial (Grgic, Lazinica et al., 2019). From this, it was concluded that individuals training for strength and hypertrophy should exercise at preferred times of day during which long-term exercise adherence may be more likely. But to our knowledge, no studies investigating time-of-day effects on resistance-exercise performance (i.e., barbell velocity, repetition volume) have controlled for time-of-day training preference. Given that previous evidence has shown that rate perceived exertion (RPE) during exercise is higher during non-preferred times of day (Kunorozva et al., 2014), diurnal alterations in power and velocity may be mediated differently when preference is accounted for. Thus, the purpose of this study was to investigate the effects of preferred and nonpreferred training times on motivation, RPE, and free-weight-bench-press performance. We hypothesized that individuals would have increased motivation, decreased RPE, and a better bench-press performance during their preferred time of day than during their non-preferred time.

Methods

Participants

To determine appropriate sample size, a priori power analysis was conducted using statistical software (G*power V 3.1.9.4). A previous investigation measuring bench-press velocity at different times of day showed increases in barbell velocity in afternoon times compared to morning times with an estimated effect size of $d = 1.0$ (Mora-Rodríguez et al., 2012). To calculate minimal sample size, the following parameters were used: test = ANOVA within-factors, effect size = 1.0, $\alpha = 0.05$, $1 - \beta = 0.8$. A minimum sample size of 10 is necessary for adequate power. Twelve healthy, resistance-trained males (age (years) = 21.0 ± 1.7; height (cm) = 179.1 ± 9.3; body mass (kg) = 80.8 ± 12.3; training experience (years) = 5.9 ± 2.5; 1-RM (kg) = 102.4 ± 19.2; relative strength [1-RM (kg)/BM (kg)] = 1.3 ± 0.2) were recruited for this investigation. *Resistance-trained* was defined as having participated in at least 2 to 3 days per week of resistance exercise (Williams et al., 2020). To screen for suitability of exercise, all participants completed a modified physical-activity readiness questionnaire (PARQ), which excluded individuals reporting an upper body injury in the past six months, cardiovascular disease, musculoskeletal disorders, or any condition that would limit exercise capacity. Prior to each trial, participants were asked to refrain from consuming substances that could alter velocity and exercise performance (i.e., caffeine, nicotine, alcohol, preworkout supplements) for a minimum of 12 hours prior to the trial and to refrain from physical activity for 24 hours prior to the trial (Degrange et al., 2019; Grgic, Mikulic, et al., 2019). Participants were asked to keep diet and sleep similar between trials. Informed consent was obtained prior to data collection and all procedures were approved by the local institutional review board (IRB).

Training-time preference and one-repetition maximum (1-RM) testing

Participants began by answering a two-question survey adapted from questions on the previously validated morningness-eveningness questionnaire (MEQ) (Horne & Östberg, 1976). We asked the following questions: (a) If you were entirely free to plan your day with no other time commitments, what time of day would you prefer to exercise? and (b) "What time of day would you choose to exercise if you wanted to perform your best? Participants designated time choices "AM" or "PM" for each question. Individuals marking both questions "AM" were designated morning preferred while those marking both "PM" were designated evening preferred (combinations were excluded). Delimitations were set to where half of the participants included preferred AM while the other half preferred PM. Subsequent one-repetition maximum (1-RM) testing was performed during each participant's preferred time of day. To determine bench-press 1-RM, participants began by completing a warmup that consisted of five repetitions at 50% and three repetitions at 70% of perceived 1-RM, separated by 2 min of rest. Following this, load was increased by 2.0 to 20.0 kg for each 1-RM attempt until the participant could not successfully complete the lift. 1-RM was obtained in ≤4 attempts with each attempt being separated by 5 min of rest. Following this, participants were familiarized with lifting with maximum explosive intent. Participants lifted a standard Olympic 20 kg barbell with maximum concentric speed for a total of three repetitions. Form was corrected if necessary.

Protocol

In a crossover, counterbalanced approach, participants completed a morning (AM; 8:00 hr) and evening (PM; 16:00 hr) trial. Immediately prior to exercise, motivation to exercise was measured using a visual analog scale (Ballmann et al., 2018). On a 100 mm line, participants marked how motivated they felt to exercise ranging from 0 (no motivation) to 100 (most motivation ever experienced). The length from 0 to the point marked was recorded as motivation to exercise. Participants then completed a light warm up consisting of five repetitions at 40% 1-RM and three repetitions at 60% of 1-RM, separated by 3 min of rest. Following the warmup and 3 min of rest, participants completed 2 sets × 2 repetitions at 75% of 1-RM with maximum concentric explosiveness separated by five minutes of rest. A linear position transducer (GymAware, Kinetitech Performance Technology, Australia) was attached to the barbell to detect mean velocity of movement. Previous work utilizing this device has validated it for velocity measurements (Orange et al., 2020). In our lab, we have observed excellent test-retest reliability of measurements during free-weight bench press (ICC = 0.932; Degrange et al., 2019; Williams et al., 2020). Velocity was averaged over the two repetitions and the highest values of the two sets were used for analysis (Williams et al., 2020). Following a 5 min rest period, participants then completed 1 set × repetitions to failure (RTF) at 75% of 1-RM. Immediately following completion, rate of perceived exertion (RPE; scale 1–10) was obtained.

Data analysis

Analysis was conducted using Jamovi software (Version 0.9) or Excel (Microsoft, USA). Confirmation of normality of distribution was confirmed using a Shapiro-Wilk test. A paired samples *t*-test was used to statistically analyze all data. Cohen's *d* effect sizes (ES) and 95% confidence intervals (CI) were calculated using an effect size calculator and were interpreted as 0.2, small; 0.5, moderate; 0.8, large. All data are presented as mean ± standard deviation (SD) and to the degree by which they could be measured. Since previous evidence has shown velocity decrements during AM times compared to PM (Mora-Rodríguez et al., 2012), absolute changes (Δ) in variables from afternoon to morning were calculated by subtracting measurements for AM and PM depending on time-of-day preference. Significance was set at $p \leq 0.05$ *a priori*.

Results

We present total repetitions and mean velocity measurements (see Figure 1). Total repetitions (reps) were not different between morning (AM) and evening (PM) trials (AM = 11 reps ± 1, PM = 11 reps ± 3; p = .993; ES = 0.04, 95% CI = −0.55–0.52). When controlling for time-of-day preference, there were no differences in total repetitions between PREF and NON-PREF trials (PREF = 11 reps ± 3, NON-PREF = 11 reps ± 2; p = .902; ES = 0.03, 95% CI = −0.23–0.23). For mean velocity ($m \cdot s^{-1}$), AM values were significantly lower than PM without controlling for preference (AM = 0.53 $m \cdot s^{-1}$ ± 0.09, PM = 0.57 $m \cdot s^{-1}$ ± 0.07; p= .025; ES = 0.43, 95% CI = 0.23–0.75). However, no differences in mean velocity existed between preferred (PREF) and non-preferred (NON-PREF) times of day (PREF = 0.57 $m \cdot s^{-1}$ ± 0.07, NON-PREF = 0.54 $m \cdot s^{-1}$ ± 0.10; p = .368; ES = 0.37, 95% CI = −0.31–0.95).

Motivation (mm) was not significantly different between AM and PM trials (AM = 65 mm ± 20, PM = 64 mm ± 14; p = .841; ES = 0.07, 95% CI = −0.15–0.26). However, motivation during the PREF time was significantly higher than the NON-PREF time (PREF = 67 mm ± 13, NON-PREF = 59 mm ± 18; p = .015; ES = 0.68, 95% CI = 0.21–0.79) (see Figure 2). No differences in RPE

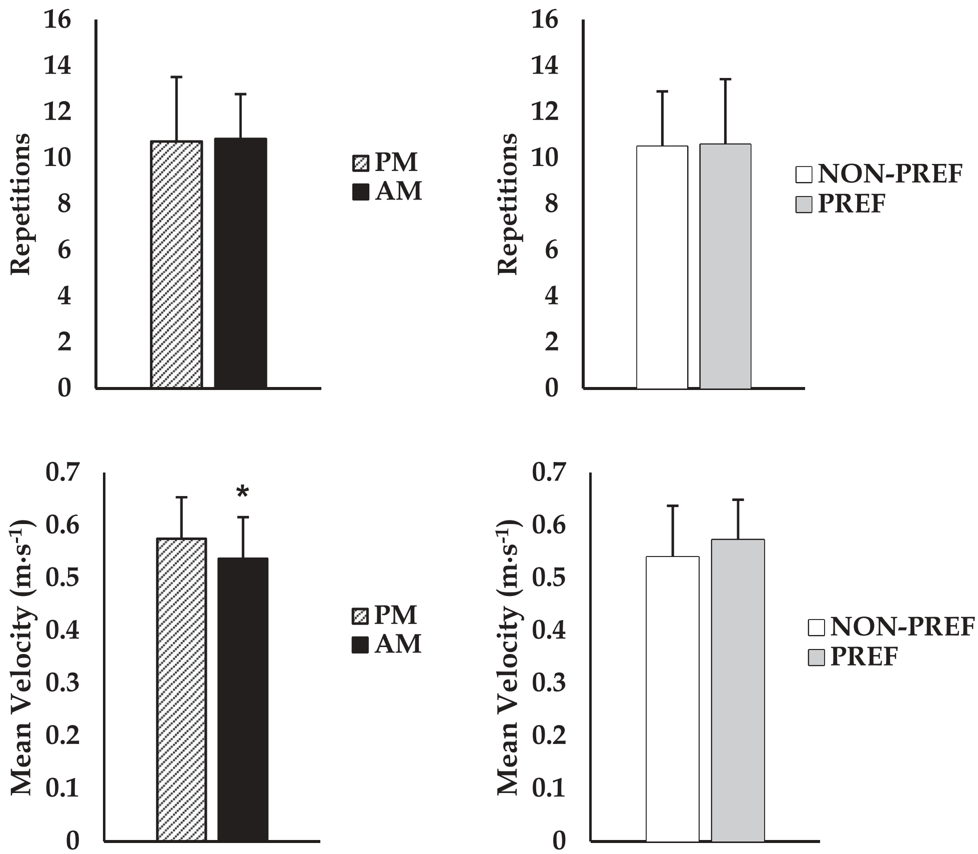

Figure 1. *Top*: Repetitions (reps) and *Bottom*: Mean velocity (m · s^{-1}) for evening (PM) versus morning (AM) and preferred (PREF) versus nonpreferred (NON-PREF) time of day. Data are presented as mean ± SD. * indicates difference from PM time is significant ($p < .05$).

(arbitrary units; a.u.) were found between AM and PM trials (AM = 5.7 ± 0.9, PM = 6.0 ± 1.2; p = .547; ES = 0.28, 95% CI = – 0.77–0.25). However, RPE was significantly lower during the PREF time than the NON-PREF (PREF = 5.5 ± 0.8, NON-PREF = 6.2 ± 1.2; p = .048; ES = 0.55, 95% CI = 0.30–1.0) (see Figure 2).

We present absolute changes in all variables during the AM versus PM according to time-of-day preference (see Table 1). For mean velocity (m·s^{-1}), velocity loss from PM to AM was significantly lower for AM-PREF than for PM-PREF (p = .002; ES = 1.13, 95% CI = 0.70–1.85). PM to AM changes in repetitions (p = .352; ES = 0.78, 95% CI = −0.07–1.78) and RPE (p = .847; ES = 0.06, 95% CI = −0.16–0.29) were not significantly different between AM-PREF and PM-PREF. However, motivation from PM to AM increased for AM-PREF while it decreased for PM-PREF (p = .029; ES = 2.27, 95% CI = 1.17–3.14).

Discussion

Findings reveal that while velocity was lower in the AM than in the PM on average for all participants, no significant differences were observed between preferred (PREF) and nonpreferred (NON-PREF) times of day. Motivation was increased and RPE was lower during the PREF time of day compared to NON-PREF. Additionally, AM-PREF participants, when compared to PM-PREF participants, tended to have lower velocity loss and higher motivation during AM times. The current study is one of few to date that have sought to describe how time-of-day training preference influences resistance-exercise performance. These results may have important applications for designing training programs to optimize adherence and maximize adaptation.

Current findings show that mean velocity during free-weight bench press was lower in AM times than in PM times without accounting for preference. This supports previous investigations that reported decreased exercise performance during AM times (Bernard et al., 1997; Mora-Rodríguez et al., 2012, 2015). Mora-Rodríguez et al. showed decreases in bench-press and back-squat barbell velocity in the AM compared to PM times (Mora-Rodríguez et al., 2012). Authors postulated that these differences may in part be attributed to diurnal changes in body temperature.

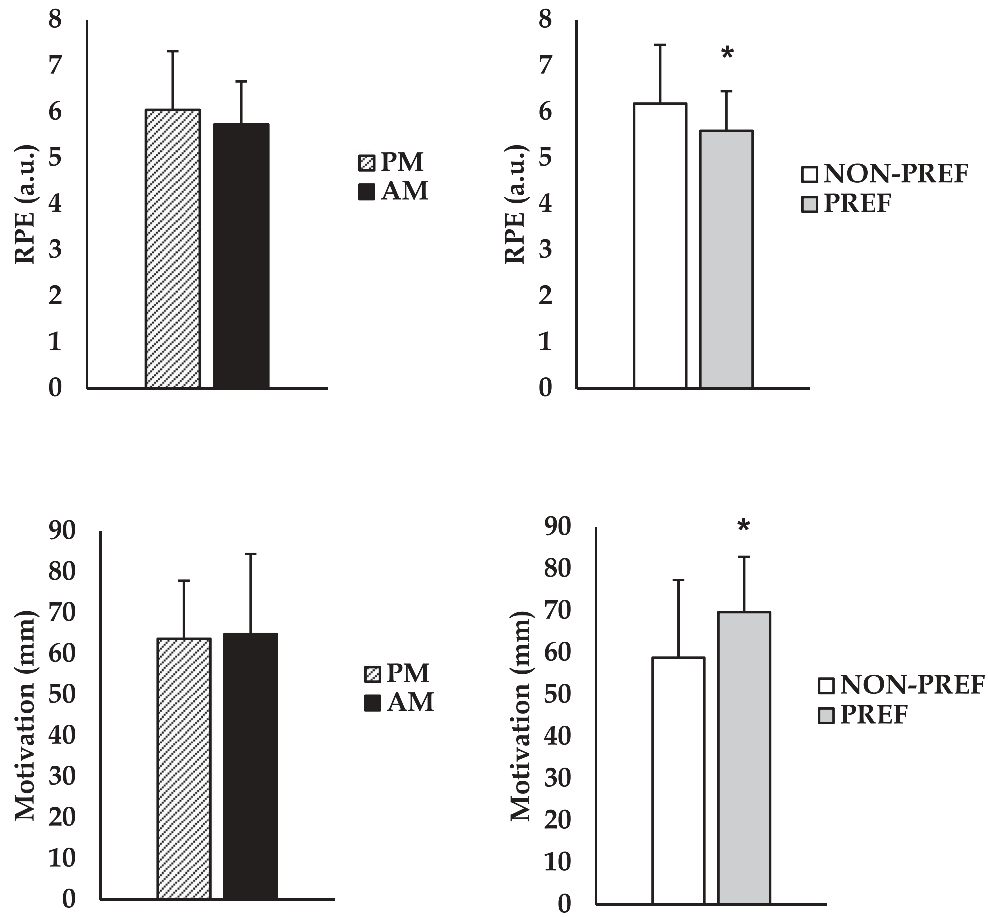

Figure 2. *Top*: RPE and *Bottom*: Motivation (mm) for evening (PM) versus morning (AM) and preferred (PREF) versus nonpreferred (NON-PREF) time of day. Data are presented as mean ± *SD*. * indicates difference from NON-PREF is significant ($p < .05$).

Table 1. Average absolute changes (Δ) from PM time to AM time.

Δ Variable	AM-PREF	PM-PREF
Δ Mean Velocity (m · s^{-1})	−0.03 ± 0.03 (−5.5%)	−0.07 ± 0.03 (−12.3%) *
Δ Repetitions (reps)	+0.80 ± 1.37 (+7.5%)	−0.40 ± 1.67 (−3.8%)
Δ RPE (a.u.)	−0.31 ± 1.33 (−5.0%)	−0.40 ± 1.14 (−6.6%)
Δ Motivation (mm)	+10.50 ± 6.80 (+14.8%)	−11.33 ± 12.34 (−38.5%) *

Average absolute changes from PM time to AM time in morning preferring (AM-PREF) and evening-preferring (PM-PREF) participants. Data are presented as mean ± *SD* (% change). * indicates difference from AM-PREF is significant ($p < 0.05$).

Power output of muscle has been reported to decrease 4% to 6% for every 1 °C decrease in muscle temperature (Bergh & Ekblom, 1979). Furthermore, increasing body temperature through warming up prior to exercise attenuates diurnal difference in countermovement jumps (Taylor et al., 2011). Changes may also be due to alterations in diurnal fluctuations in humoral hormone concentrations, which may have implications in chronic anabolic signaling (Chtourou et al., 2014; Sedliak et al., 2007). Interestingly, differences in velocity were abolished when controlling for time-of-day training preference. Furthermore, the AM-PREF group had lower losses in barbell velocity between PM and AM times compared to PM-PREF. This could in part be due to habituation if participants regularly train at the PREF times of day, washing out differences and attenuating decrements in performance after accounting for preference. This is plausible as individuals are more likely to exercise during times of day that they prefer (Hisler et al., 2016). Evidence has shown that eight weeks of training at the same time of day attenuates circadian changes in strength, power, and resistance-exercise performance (Chtourou et al., 2012). Chronic training during AM times has been shown to improve lower AM performance over time likely due to habituation (Chtourou & Souissi, 2012). While preference of time of training was currently assessed, timing of current training regimens for participants was not directly measured, leaving the interaction between habituation and time of day training preference unknown. Despite changes in AM and PM velocity measures, no changes in total repetitions were seen between AM times versus PM times or PREF versus NON-PREF times. These results may be due to diurnal changes in muscle force and power output not being sustained over repeated contractions, thereby, not affecting exercise volume. Indeed, Racinais et al. measured anaerobic power over short, repeated sprints and reported that power output was lower in the morning only in the first of five sprints while no differences were seen for subsequent bouts (Racinais et al., 2005). Furthermore, Zarrouk et al. showed no diurnal changes in electromyographic readings or neuromuscular efficiency during repeated sprints albeit peak power was maintained to a greater degree during evening times (Zarrouk et al., 2012). Whether muscle activation is affected over repeated exercise differently during PREF and NON-PREF times of day is unknown. Effort during exercise is typically higher during PREF conditions and higher effort is associated with increased motor unit recruitment (Belanger & McComas, 1981). However, diurnal variations in strength may decrease with habituation and chronically lead to similar adaptations regardless of training time (Grgic, Lazinica, et al., 2019). Thus, more investigation into differences of quality of reps (i.e., maintenance of velocity, motor unit recruitment, amount of muscle activation) versus quantity (i.e., total repetitions, volume-load) is needed regarding time-of-day preference and resistance-exercise performance to identify more implications for chronic adaptations with training.

RPE was not different between AM and PM times in the present study. Supporting this, Focht et al. reported that pain ratings and threshold following resistance exercise were not different with variations in time of day (Focht & Koltyn, 2009). However, RPE was significantly lower during PREF times of day versus NON-PREF. Evidence on trained cyclists showed that athletes who preferred training in the AM reported lower RPE with incremental exercise during AM times compared to PM times (Kunorozva et al., 2014). Additionally, Rossi et al. reported that RPE is lower during walking at preferred times of day yet with no changes in physiological variables (Rossi et al., 2015). Changes in RPE with time-of-day training preference may be due to differences in affective responses to exercise. Individuals may have higher enjoyment and more-positive views of exercise during their PREF times of day (Schaal et al., 2010). Lower RPE seen during PREF times of day may have important implications for exercise adherence. Previous work has shown that affective responses to exercise may be intensity dependent leading to alterations in future exercise behavior (Ekkekakis et al., 2008). Furthermore, Krinski et al. showed decreases in RPE during exercise accompany increases in exercise enjoyment leading to improvements in future intention to exercise (Krinski et al., 2017). Thus, while current findings suggest no improvements in performance regardless of time-of-day preference, individuals participating in resistance exercise during preferred times of day may find exercise more enjoyable due to lower RPE and may be more likely to commit to a regular training regimen. However, we caution that exercise enjoyment was not measured leaving a need for future investigation on how chronic preferred time-of-day training changes affective responses to exercise and adherence. Motivation did not differ between AM and PM trials. When controlling for time-of-day training preference, motivation was significantly higher during PREF times versus NON-PREF times. Furthermore, for the AM-PREF group, motivation increased robustly in the AM compared to PM, and for the PM-PREF group, motivation decreased in the AM compared to PM. Motivation of behavior, including physical activity, has been suggested to be largely influence by circadian rhythms (Antle & Silver, 2015). Supporting our findings, studies have found that athletes are more motivated to participate in sports during their preferred time of day to train (Lastella et al., 2016). Like changes in RPE, improvements in motivation could have practical importance for exercise behavior. Athletes may be more motivated to exercise during times within their chronotype (Vitale & Weydahl, 2017). Higher intrinsic motivation is associated with improved exercise adherence (Ryan et al., 1997). Altogether, individuals training at PREF times of day may experience increased motivation, compared to NON-PREF times of day, which could benefit exercise behavior, though as previously mentioned, more exploration is needed on how chronic resistance training during PREF versus NON-PREF times influences adaptive responses to exercise.

While the present investigation provides novel information on time-of-day training preference and resistance-exercise performance, the research has limitations. As previously mentioned, habituation to time-of-day training was not strictly controlled for. Previous evidence has suggested that habituation to time of training may influence diurnal variations of peak power and strength (Chtourou et al., 2012; Souissi et al., 2002). Thus, further study is needed to determine whether habituation influences resistance-exercise performance during preferred and nonpreferred times. Currently, only a single resistance-exercise bout to failure was used. Results may not be generalizable to sustained repeated exercise bouts frequently used by individuals engaging in resistance training. However, a previous investigation on repeated sprint ability did not show time-of-day fluctuations in repeat performance (Racinais et al., 2005). Lastly, only one AM time and one PM time were used, which does not encompass individuals who may exercise in the middle of the day. Studies using more-precise training times are needed and could potentially show different results for how time-of-day training preference influences performance.

In conclusion, the present investigation reveals that performing resistance exercise at AM times results in poorer performance compared to performing resistance exercise at PM times. However, training during preferred times of day did not enhance resistance-exercise performance. Individuals preferring AM times of training had lower velocity loss from PM to AM. Motivation was higher and RPE was lower during preferred times of day. Collectively, current results support the importance of training at preferred times of day while also showing that individuals who prefer AM times may have lower decrements in performance due to diurnal fluctuations. From a practical standpoint, these data suggest that exercising at preferred times of day may benefit motivation and lower perceived intensity, which could ultimately lead to better effort during training sessions. Furthermore, athletes who prefer training in the morning may have attenuated decrements in velocity during morning training sessions. Thus, coaches and practitioners looking to increase motivation and decrease perceived exertion could consider allowing athletes to train at preferred times of day if feasible.

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