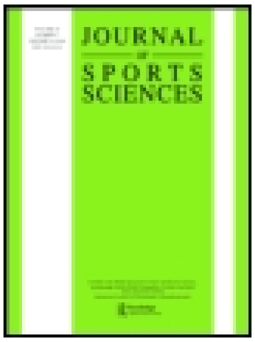

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Circadian rhythm effect on physical tennis performance in trained male players

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ABSTRACT

To determine the effect of circadian rhythm on neuromuscular responses and kinematics related to physical tennis performance, after a standardised warm-up, 13 highly competitive male tennis players were tested twice for serve velocity/accuracy (SVA), countermovement vertical jump (CMJ), isometric handgrip strength (IS), agility T-test (AGIL) and a 10-m sprint (10-m RUN). In a randomised, counter-balance order, tennis players underwent the test battery twice, either in the morning (i.e., AM; 9:00 h) and in the afternoon (i.e., PM; 16:30 h). Paired *t*-tests were used to analyse differences due to time-of-day in performance variables. Comparison of morning versus afternoon testing revealed that SVA (168.5 ± 6.5 vs. 175.2 ± 6.1 km $\cdot$ h^{-1}; $P = 0.003$; effect size [ES] = 1.07), CMJ (32.2 ± 0.9 vs. 33.7 ± 1.1 cm; $P = 0.018$; ES = 1.46), AGIL (10.14 ± 0.1 vs. 9.91 ± 0.2 s; $P = 0.007$; ES = 1.23) and 10-m RUN time (1.74 ± 0.1 vs. 1.69 ± 0.1 s; $P = 0.021$; ES = 0.67) were significantly blunted during the morning testing. However, IS was not affected by time-of-day ($P = 0.891$). Thus, tennis performance may be reduced when competing in the morning in comparison to early evening. Therefore, coaches and tennis players should focus on schedule the SVA, power, speed and agility training sessions in the afternoon.

ARTICLE HISTORY
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KEYWORDS
Time-of-day; running sprint; counter movement jump; agility test; tennis serve velocity

Introduction

Circadian rhythms (CRs) are cyclic variations which take place in a 24-h period in each living being and can be explained by several mechanism like external changes in the environment (exogenous), sleep–wake cycle and internal (endogenous) changes in the biological clock (Reilly & Waterhouse, 2009). CRs involve variations in basal body temperature and blood concentration of hormones (i.e., testosterone, cortisol), which in turn could affect body fluids, metabolite excretion and cardiac response (Atkinson & Reilly, 1996). Furthermore, CRs may affect physical performance by altering actin–myosin bridging process (Decostre, Bianco, Lombardi, & Piazzesi, 2005), phosphagen metabolism and/or muscle-buffering capacity (Atkinson & Reilly, 1996; Starkie, Hargreaves, Lambert, Proietto, & Febbraio, 1999). CRs affects not only short-term efforts that rely on muscle strength and power output (i.e., maximal force production; Pallares et al., 2015; Teo, McGuigan, & Newton, 2011) but also long-term endurance exercise performance (i.e., 16.1-km race; Atkinson, Todd, Reilly, & Waterhouse, 2005). The morning reductions in physical performance can be observed during simple motor tasks as pedalling (Moussay et al., 2003) or as well as during complex motor tasks as swimming (Kline et al., 2007) and soccer (Reilly et al., 2007). Several mechanisms have been involved in the diurnal variation on performance. Body temperature variations through the day have been related to the differences in physical performance observed during the afternoon in comparison to the morning (Kline et al., 2007).

Some individuals manifest to be more energetic at a specific time-of-day and the identification of that moment (e.g., morning, afternoon) reveals their individual “chronotype” (Teo et al., 2011). In addition, Hill, Cureton and Collins (1989) reported that participants who trained in the morning had relatively higher post-training values of cardiorespiratory fitness (ventilatory threshold) in the morning, while participants who trained in the afternoon had relatively higher values in the afternoon. This finding is in agreement with additional data which support that the time-of-day of habitual training could modulate the chronotype (i.e., natural tendency) and affect the time-of-day where the peak physical performance occurs (Rae, Stephenson, & Roden, 2015). All the above-mentioned findings suggest that CRs can affect through different mechanisms athletic performance, and therefore, the effects of diurnal variation in each specific sport should be studied.

As it happens with other intermittent sports, tennis could be influenced by CRs (Atkinson & Speirs, 1998; Reilly et al., 2007). Tennis involves intermittent, high-intensity efforts interspersed with periods of low-intensity activity (e.g., active recovery between points and rest between changeovers breaks), over a variable period of time (i.e., 1–5 h; Davey, Thorpe, & Williams, 2003; Fernandez, Mendez-Villanueva, & Pluim, 2006). Agility (Roetert, Garrett, Brown, & Camaione, 1992), strength and power output (Girard & Millet, 2009) and serve velocity (Ulbricht, Fernandez-Fernandez, Mendez-Villanueva, & Ferrauti,

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2016) have been associated with tennis physical performance. Atkinson and Speirs found that serve velocity was increased in the afternoon when compared to the morning (Atkinson & Speirs, 1998). However, to our knowledge, no study has examined the effects of CRs on additional physical tennis-related qualities, such as power, agility, running speed and handgrip strength.

Therefore, the aim of this study was to determine the effects of CRs on neuromuscular responses associated with tennis physical performance. Based on previous research (Mora-Rodriguez, Garcia Pallares, Lopez-Samanes, Ortega, & Fernandez-Elias, 2012), we hypothesised that neuromuscular performance and kinematics related to tennis will be blunted in the morning in comparison to the afternoon in competitive male tennis players.

Methods

Participants

Thirteen highly competitive male tennis players with age 22.5 ± 3.7 years, body weight 78.6 ± 10.0 kg, height 1.82 ± 0.08 m, BMI 23.6 ± 2.26, tennis experience 12.2 ± 3.7 years were recruited to participate in the study. All participants were asked to report their habitual training schedule in order to design testing around those time-of-day. Four tennis players had an ATP ranking (i.e., professional tennis ranking) between 750 and 1800, and 9 were among the 300 best Spanish senior tennis players. The players and parents/guardians (3 participants under 18 years old) were informed of all experimental procedures, and written informed consent was completed before participation. The University of Murcia Bioethics Commission approved the study which complied with the recommendations of the Declaration of Helsinki.

Experimental procedure

Figure 1 displays the used experimental design. In a randomised counter-balance order, tennis players underwent the same physical test battery on the morning (AM) or in the afternoon (PM): (1) AM–PM protocol started with a morning session at 9:00 h which was repeated in the afternoon at 16:30 h. (2) PM–AM protocol started with an afternoon session, which was repeated the following morning. The chosen testing time-of-day (9:00 h and 16:30 h) were selected according to the reported habitual training and competition schedules. Before testing, participants underwent two familiarisation sessions with the experimental test battery to prevent bias from progressive learning. Familiarisation sessions were performed at the same times used in the study (9:00 h and 16:30 h). Testing battery consisted of a serve velocity/accuracy test (SVA), a countermovement vertical jump (CMJ), a maximum isometric handgrip strength test (IS), an agility T-test (AGIL) and 10-m sprint (10-m RUN). To ensure standardisation of the measurements, all tests were performed in the same order and using the same testing devices which always were handled by the same researcher. To minimise the effects of environmental conditions, testing was performed in the early fall where the morning and afternoon temperatures are not too different.

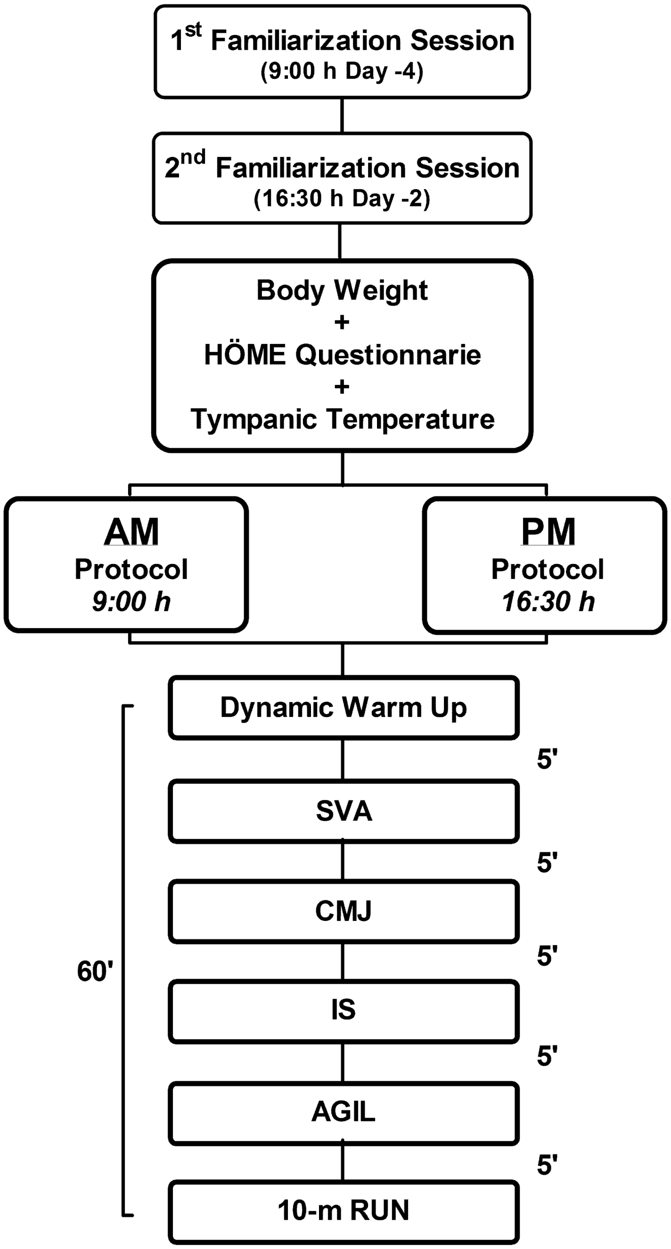

Figure 1. Experimental design flow chart. Trials were performed in separated days in a randomised and balanced order. SVA: Serve velocity/accuracy; CMJ: counter movement jump; IS: isometric handgrip strength; AGIL: agility T-test; 10-m RUN: 10-m sprint.

Experimental protocol

During the 24-h prior to testing, participants refrained from any strenuous activity other than that required by the experimental trials. In addition, participants were instructed to refrain from using any source of caffeine for 5 days before experimental trials. With the aim of standardise the diet intake before testing sessions, the night before the morning testing session, participants ingested an easy digestible meal with a total energy intake of 665 kcal (50% carbohydrates, 30% fats and 20% proteins) at 21:00 h. For the afternoon testing sessions, participants ingested the same meal at 13:00 h. The day before beginning the experimental testing, participants' height was measured to the nearest 0.5 cm using a wallmounted stadiometer (Seca 202, Seca Ltd., Hamburg, Germany). For the morning testing sessions, participants arrived to the testing facility at 8:20 h (40 min before testing) in a fasting state (PRE). Body composition was assessed by bioimpedance (Tanita B-601, Tanita Corp., Tokyo, Japan). For the afternoon sessions, participants arrived to the testing facility at 15:50 (i.e., 40 min before testing). After the body composition assessment, participants ingested 330 mL of a fruit milkshake (168 kcal) and a pastry (456 kcal) which were served as a standardised breakfast in the AM trials or as a snack in the PM trials (total of 624 kcal and 68 g of carbohydrates). Following, participants completed the Horne–Östberg Morningness–Eveningness (HÖME) personality questionnaire (Horne & Ostberg, 1976), in order to assess their individual chronotype. After the questionnaire completion, tympanic temperature (Ttym) was assessed with a portable thermometer (Thermoscan, Braun, Germany) in triplicate after the removal of earwax when needed. Approximately 10 min after the meal, participants performed a standardised warm-up (4 min running at low intensity and 4 min of exercises with and without a racket). SV, AGIL and 10-m RUN were performed in a hard tennis court (Greenset surface, GreenSet Worldwide SL, Spain). CMJ and IS were tested in a room nearby the tennis court.

HÖME test

The HÖME questionnaire (Horne & Ostberg, 1976) was used to determine the participants' chronotype (morning or evening). The questionnaire consists of 19 questions related to sleep/wake behaviour and yields scores ranging from 16 to 86. Based on their scores, individuals were placed into one of five chronotype categories: 16–30: definite evening type, 31–41: moderate evening type (MET), 42–58: neither type (NT), 59–69: moderate morning type (MMT) and 70–86: definite morning type.

SVA test

A radar gun (Pocket Radar Ball Coach PR1000-BC, Republic of South Korea) was used to measure first serve velocity. The radar was positioned at the centre of the baseline, 4-m behind the server, aligned with the approximate height of ball contact and pointing down the centre of the court. The SVA test started with a warm-up consisting in 5 second serves and five first serves at submaximal effort (≈80%). SVA test was then conducted aiming to achieve five accurate serves at maximal speed in the lesser number of serves. Only serves that entered a 1 × 1-m serve area placed in the farther diagonal corner of the serve area were accounted. The average speed of the first five serves that entered the limited area (1 m^2) was registered. Pilot data in 13 participants in two separated days to test reproducibility revealed an intraclass coefficient correlation (ICC) of 0.92 and a coefficient of variation (CV) of 3.5%.

Countermovement vertical jump (CMJ)

Participants completed three repetitions of a CMJ using an infrared jump system (Optojump, Microgate, Italy) according to standard methodology (Bosco, Luhtanen, & Komi, 1983). Each participant performed three maximal CMJ interspersed with 45 s of passive recovery. The highest height out of the three jumps was recorded. Test–retest ICC and CV were 0.9% and 3.2%, respectively.

IS

Two maximum isometric voluntary contractions were measured from the dominant and non-dominant hand using a calibrated handgrip dynamometer (Takei 5101, Tokyo, Japan). Volunteers sat with 0 degrees of shoulder flexion, 0 degrees of elbow flexion and the forearm and hand in a neutral position. The highest value out of two attempts was recorded as the maximum voluntary handgrip strength. Pilot data in 13 participants in two separated days to test reproducibility revealed an ICC and CV of 0.99 and 4.1%, respectively.

AGIL

AGIL was conducted using the protocol outlined by Pauole, Madole, Garhammer, Lacourse and Rozenek (2000). Participants began the test with both of their feet behind starting point A. After an acoustic signal, they had to sprint 9.14-m forward to point B and touch a cone. Then, they shuffled 4.57 m to the left and touched cone C. After that, they shuffled 9.14 m to the right and touched cone D, and then they shuffled again 4.57 m to the left back to point B. Finally, participants ran backward passing the finish line at point A. Two electronic time sensors (Smartspeed, Fusion Sport, Australia) were set 1 m above the surface and positioned 3 m apart facing each other on either side of the starting line. Participants began each test 30 cm behind the starting line, and the timer started when they passed the first gate. The best performance out of two repetitions (separated by a 2-min recovery period) was recorded for subsequent analysis. Pilot data in 13 participants in two separated days to test reproducibility revealed an ICC and CV of 0.945 and 1.2%, respectively.

10-m RUN

Time during a 10-m dash in a straight line was measured using two photocell gates placed 1.0-m above the ground level (Smartspeed, Fusion Sport, Australia). Each sprint was initiated from a standing position, 30-cm behind the photocell gate, which started a digital timer. Another photocell gate was placed at the finish line to stop the timer. The best performance out of two repetitions (separated by 1 min recovery period) was recorded for subsequent analysis. The ICC and CV of this measurement were 0.90 and 2.6%, respectively.

Environmental conditions

During the whole duration of each testing session, air temperature and humidity were measured with a portable weather station (WMR 108, Mextech, India). Data were averaged to obtain the mean morning and afternoon temperature (°C) and relative humidity (%).

Statistical analysis

Data are presented as means and standard deviation. The Shapiro–Wilk test was used to assess normal distribution of data. All variables were compared using T-test for related variables (AM vs. PM). The significance level was set at $P \leq 0.05$. Cohen's formula for effect size (ES) was used and the results were based on the following criteria: trivial (0–0.19), small (0.20–0.49), medium (0.50–0.79) and large (0.80 and greater) (Cohen, 1992). Performance variables were correlated (r Pearson) with HÖME questionnaire. All the statistical analyses were done using the SPSS software version 18 (SPSS Inc., Chicago, IL, USA).

Results

Environmental temperature, Ttym, habitual training scheduled, and HÖME

During the morning sessions, air temperature was 20.1 ± 0.9°C and relative humidity was 40 ± 3%. During the afternoon sessions, air temperature was 24.0 ± 1.7°C and relative humidity was 44 ± 2%. Ttym was significantly elevated by 1.4% in the PM versus AM trial (36.5 ± 0.4 vs. 36.0 ± 0.3°C, respectively; $P < 0.001$; ES = 1.45). All participants reported that their habitual training schedule included two training sessions per day (around 9:00 AM and 17:00 in the PM). Regarding the participant's chronotype assessed by the HÖME questionnaire, nine participants (69.2%) scored as "NT", three participants (23.1%) as "MET" and one participant (7.6%) as a "MMT".

SVA test, countermovement vertical jump height (CMJ) and IS

The serve velocity test was 4.0 ± 4.2% higher during the PM session compared with the AM session ($P = 0.003$; ES = 1.07; Figure 2(a)). The CMJ height was 4.5 ± 5.1% higher during the evening session than during the morning session ($P = 0.018$; ES = 1.46; Figure 2(b)). However, no differences were recorded in IS neither in the dominant nor in the non-dominant hand ($P = 0.962$ and 0.891; respectively).

AGIL and 10-m RUN

During the second session of testing, one volunteer reported an anterior knee pain that prevented him from running the 10-m RUN and T-test which were the last measurements of the test battery. Data of AGIL and 10-m RUN from his first testing session were not included in the analysis. The time required to complete the AGIL test in the afternoon (PM) was 2.1 ± 2.0% lower than in the morning (AM) ($P = 0.007$; ES = 1.23; Figure 2(c)). The time elapsed during the 10-m RUN was 2.7 ± 3.0% shorter in the PM compared to the AM ($P = 0.021$; ES = 0.67; Figure 2(d)).

Correlations

None of the correlations between HÖME questionnaire scores and the time-of-day related differences in the measured neuromuscular qualities reached statistical significance; SVA ($r = 0.144$; $P = 0.639$), CMJ ($r = 0.198$; $P = 0.536$), IS

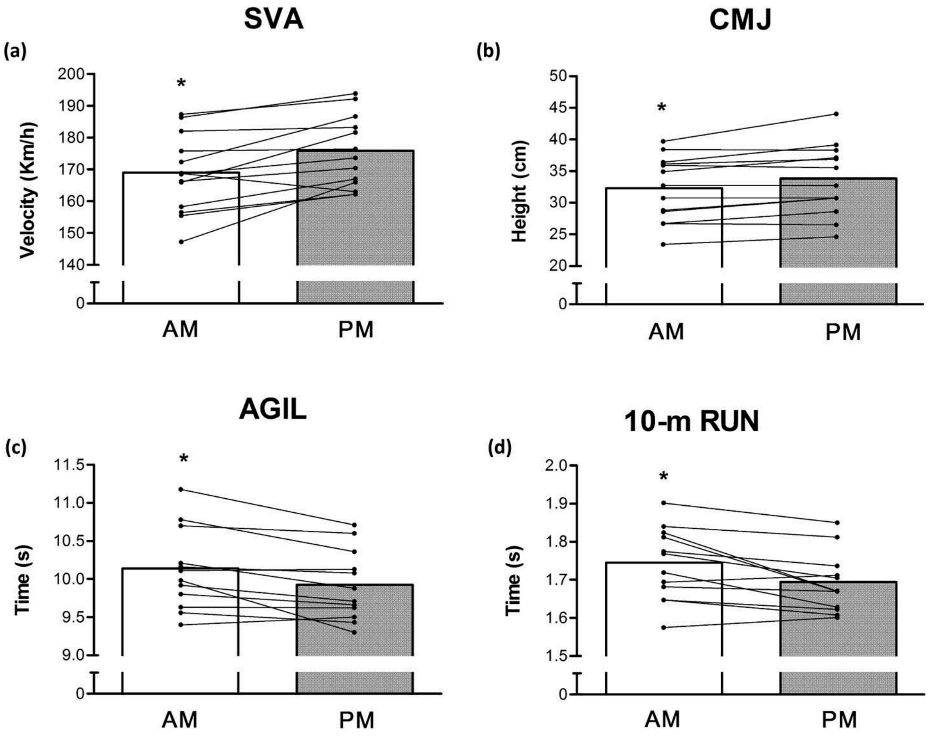

Figure 2. Effects of circadian rhythm on (a) SVA: serve velocity/accuracy; (b) CMJ: countermovement vertical jump height; (c) AGIL: time in an agility test and (d) 10-m RUN: time in a 10-m dash. *Significant differences compared to the PM values at $P \leq 0.05$.

($r = 0.266$; $P = 0.380$), AGIL ($r = 0.083$; $P = 0.786$) and 10-m RUN ($r = 0.510$; $P = 0.075$).

Discussion

The current study examined the effects of CRs on physical tennis performance. To accomplish this aim, we assessed the effects of two separated time-of-day (i.e., 9:00 h and 16:30 h) in a group of neuromuscular responses and kinematics which could be determinant for physical tennis performance. The time-of-day presently chosen is habitual for training and competition in ATP-ranked tennis players. The main finding of our study is that in well-trained male tennis players, neuromuscular responses and kinematics are blunted in the morning (AM) in comparison to the afternoon (PM). For instance, SVA, countermovement vertical jump (CMJ), AGIL and 10-m RUN were 2–4.5% lower in the morning. These differences apparently not large (i.e., 2–4.5%) could be decisive during high level competition where small differences have a large impact in the result of a match.

To our knowledge, only one study has examined the time-of-day effect on one particular but important aspect of tennis performance (i.e., tennis serve). Atkinson and Speirs (1998) reported a 3.7% decrease in first serve velocity at 9:00 h in comparison to when tested at 18:00 h. This outcome is similar to the presently reported data (4.0% lower in the morning; Figure 2(a)). While in their experiment they emphasise speed in the first serve and accuracy in the second, our test integrated both components (accuracy and velocity) on the first serve, since only serves that enter a 1 × 1-m area were accounted. Thus, expanding the findings of Atkinson and Speirs, we used a serving test that resembles a real-game serve situation (combination of speed and accuracy) to demonstrate a diurnal variation on tennis serve.

A significant decline (i.e., 11.2%) in CMJ performance has been observed in well-trained tennis players after a 4-h tennis match, which simulates five sets tennis matches as in Grand Slams (e.g., Australian Open) or David Cup (i.e., world male cup of tennis; Gescheit, Cormack, Reid, & Duffield, 2015). Despite CMJ is a well-validated test for assessing neuromuscular power (Gathercole, Sporer, Stellingwerff, & Sleivert, 2015), there are no reports of diurnal variation on CMJ in tennis players. In rugby players, there is a 4.3–5.1% reduction in CMJ performance in AM versus PM (Taylor, Cronin, Gill, Chapman, & Sheppard, 2010; West, Cook, Beaven, & Kilduff, 2014) which agrees with the data from our study (4.5% decline). The currently reported 4.5% decline in the AM values could result detrimental for the outcome of a tennis match since many movements on court are composed by explosive maximal leg contraction similar to those tested by the CMJ.

Agility has been related to tennis performance, since, during a tennis point, players complete an average of 4 directional changes per point, reaching up to 15 directional changes during long rallies (Kovacs, 2009). In fact, agility has been proposed by Roetert et al. (1992) as the only physical performance variable predictive of competitive rankings in young male tennis players. In other sports like soccer, agility has been shown to be influenced by CRs (Reilly et al., 2007). Reilly et al. reported a 10.7% decrease in agility values (tested using a dribbling test) during the morning, in comparison with the afternoon (8:00 h vs. 16:00 h). We presently found a lower decrease (2.1%), which still reached statistical significance. Reilly et al. used a soccer-specific agility test, and presently, we used a generic agility test. Thus, methodological differences could explain the discrepancies in the diurnal variation observed between both studies. Running times over 10–15-m dash have been used to evaluate acceleration ability in other sports (Cronin & Hansen, 2005). During a tennis point, players run an average of 3 m per shot and a total of 8–12 m per point including direction changes (Fernandez et al., 2006) while rarely a point exceed 15 m sprints. Accordingly, we chose a 10-m RUN test as a representation of the average sprint distance during a point in competitive tennis. Racinais, in 2005, assessed leg power using the repeated sprint ability test and found that power in the first sprint is 4.7% lower in the morning (7:00–9:00 h) than in the afternoon (17:00–19:00 h) (Racinais, Connes, Bishop, et al., 2005). In a similar fashion, our data showed a 2.7% decrease in the velocity achieved during the 10-m RUN performed in the morning in comparison to the afternoon. Sargeant (1987) found that increases in body temperature observed during the afternoon were associated with a higher activation of fast twitch fibres. His findings demonstrated an additional mechanism behind the higher performance in the afternoon, in this case for sprint-type tasks. In addition, the increase in body temperature observed during the afternoon could enhance sprint performance via increases in the speed of muscle contraction, decreases in the time required to reach peak tension and reductions in relaxation times (Mohr, Krustrup, Nybo, Nielsen, & Bangsbo, 2004). Since diurnal variation does not affect VO_2 kinetics (Faisal, Beavers, & Hughson, 2010), it is possible that only short duration and explosive actions (i.e., sprint velocity), and not overall endurance, could be different between morning and afternoon. Thus, our study shows that agility and short-distance running velocity (allegedly related to tennis performance) are both decreased in the morning in comparison to the afternoon.

IS measurements did not respond as the previously mentioned variables since we could not detect time-of-day differences. Our findings are similar to previous reports where IS did not change instead of changes in other neuromuscular variables as CMJ and bench press contraction velocity (Pallares et al., 2016). A possible explanation to this phenomenon could be that decreases in the ability of the central nervous system to stimulate the muscle as seen during hypohydration or early morning are not evident when contraction time is not a limitation for motor unit recruitment.

Although the HÖME questionnaire is a well-recognised tool for detecting morningness and eveningness chronotype, according to our data, it does not correlate with physical performance in highly competitive tennis players. Of note, most of our players (69%) did not fit in any of the two defined chronotypes. Thus, it was not surprising the lack of association between the HÖME questionnaire and our neuromuscular performance data. On the other hand, the association between performance in sports and CRs has been widely described. Baxter and Reilly(1983) found that swimmers showed a higher exercise capability during the evening. Their findings were lately confirmed during sprint swimming (Pallares et al., 2014). Both studies showed that the higher swimming performance was strongly associated with the circadian curve of body temperature which peaks at the afternoon. Similar findings have been reported for intermittent sports (e.g., soccer; Reilly et al., 2007). In agreement with the findings in soccer players, our data showed that body temperature in the afternoon was 1.4% higher than in the morning. During a tennis match, short duration and explosive actions are frequently performed (e.g., serve, sprints) which are associated with tennis performance. Racinais and Oksa (2010) found that during short-duration muscular actions, performance improves between 2% and 5% per each degree increase in the muscle temperature. In agreement, our tennis players showed higher values (2–4.5%) for all variables during the afternoon (except handgrip). It is remarkable that mild increases in muscle temperature have been associated with increases in conduction velocity (Rutkove, Kothari, & Shefner, 1997) and muscle contractility (Racinais, Bloc & Jonville, et al., 2005). However, the effect of temperature upon peripheral nerve function is not linear, with increase in muscle conduction velocity and contractility with the initial increases in temperature (e.g., 20–30°C; Todnem, Knudsen, Riise, Nyland, & Aarli, 1989) but disappearing when core temperature is too elevated (i.e., hyperthermia; Racinais, 2010). Although the diurnal variation of body temperature has a strong influence on physical performance, it has been proposed that it is not the only mechanism behind the differences between morning and afternoon. Racinais, Blonc, & Hue, (2005) found that time-of-day enhances muscular power during maximal cycle sprints, whereas a warm-up performed before testing failed to increase this parameter. Thus, although body temperature explains part of the diurnal variation in performance, the effects of time-of-day are not only due to changes in body temperature (Reilly & Waterhouse, 2009).

Tennis matches and training sessions are frequently scheduled in the morning. With the aim of minimising the diurnal variation on performance, several strategies have been proposed. Taylor, Cronin, Gill, Chapman and Sheppard (2011) used an extended warm-up in the morning sessions to increase body temperature which is reflected in in a 9.2% increase in CMJ power that however did not reach statistical significance. In addition, Kilduff, West, Williams and Cook (2013) used passive heating to avoid declines in core temperature and peak power output during a repeated spring ability test performed in the morning (i.e., 10:00 h). Unfortunately, they did not compare the same intervention in the afternoon. In our laboratory, we have recently reported that the ingestion of a dose of caffeine (6 mg · kg^{-1}) counteracts the muscle contraction velocity declines observed in the morning in resistance-trained athletes (Mora-Rodriguez et al., 2015). To our knowledge, those strategies have not been used in tennis. However, recognition of the performance effects associated with CRs in competitive tennis players is a first step towards the implementation of strategies to mitigate or eliminate the decreased performance observed in the morning.

This study has some limitations worth to mention. Tennis players were in the ATP ranking or within the 300 best tennis seniors' players of the country. However, we have a limited sample size (*n* = 13) due to the busy schedule of professional tennis players. In addition, we only tested two time points (9:00 and 16:30 h) of the whole CRs spectrum and maybe the differences in performance presently found could be larger if other testing times are included (i.e., 20:00 h). However, testing times (9:00 and 16:30 h) were the most habitual training time-of-day among our professional tennis players. The other main limitation of our research is that as usually occurs, environmental conditions varied during the training morning and afternoon sessions. However, testing sessions were scheduled in the early fall, when morning and evening temperatures were similar (difference of 4°C) and we expect a minimal influence of this environmental situation. Evidences about the effects of ambient temperature on human performance are contradictory. In a first instance, Ball, Burrows and Sargeant (1999) showed that increases in ambient temperature from 19 to 30°C were associated with increases in peak and mean power (25% and 15%, respectively) during a Wingate test. However, 1-year later, under similar environmental conditions (23 vs. 31°C), and also measuring the peak and mean power during a Wingate test, Backx, McNaughton, Crickmore, Palmer and Carlisle (2000) could not replicate this changes described by Ball et al. To expand the controversy about the effects of ambient temperature, Sargeant demonstrated that warming the legs in a 44°C water bath increased muscle temperature and maximal cycling power in a 20-s test when compared to thermoneutral conditions (Sargeant, 1987). In contrast, years after the study of Stanley, Kraemer, Howard, Armstrong and Maresh (1994) showed no significant difference in physical performance replicating the experimental design of Sargeant. Thus, to our knowledge, there are not enough evidence supporting the precise influence of the 4°C of difference in the ambient temperature presently observed between our morning and afternoon trials. However, it seems that particularly for simulated tennis matches, differences of ambient temperature from 22 to 36°C were not associated with differences in physical performance assessed with measurements similar to those used in our study (i.e., countermovement vertical jump, sprint performance with and without changes of direction (Girard, Christian, Racinais, & Periard, 2014)). Finally, ambient warming from morning to afternoon is a natural phenomenon typically encountered in a tennis tournament which makes our performance data more applicable to a real tennis competition.

Conclusion

Our results reveal that the scores in physical tests directly (i.e., tennis SVA) or indirectly (i.e., jumping ability, running agility and peak running velocity) related to tennis performance are significantly lower in the morning (9:00 h) compared to the afternoon (16:30 h). This mild reduction in performance in the morning may have an important impact in the outcome of a match in professional tennis players. The study showed superior tennis physical performance in the afternoon, thus coaches and tennis players should focus on schedule the velocity serve/accuracy, power, speed and agility training sessions in the afternoon.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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