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Effect of chronotype on motor skills specific to soccer in adolescent players

E. Roveda ^{a,b}, A. Mulè ^a, L. Galasso ^a, L. Castelli ^a, R. Scurati ^a, G. Michielon^a, F. Esposito ^{a,b},
A. Caumo ^a, and A. Montaruli ^{a,b}

^aDepartment of Biomedical Sciences for Health, University of Milan, Milan, Italy; ^bIRCCS Istituto Ortopedico Galeazzi, Milan, Italy

ABSTRACT

Circadian rhythms influence daily behavior, psychological and physiological functions, as well as physical performance. Three chronotypes are distinguished according to the preferences people typically display for activity at certain times of day: Morning, Neither, and Evening types (M-, N- and E-types). The chronotype changes with age: eveningness tends to be stronger in youth and morningness in older age. The progressive shift toward eveningness during adolescence creates misalignment with morning society schedules and can lead to a deterioration in intellectual and physical performance. Soccer is one of the world's most popular sports practiced by adolescents and soccer workouts are usually held after school in the afternoon or evening. Performance in soccer is related to a host of factors, including physiological variables and motor skills that have a circadian variation. The aim of this study was to determine the effect of chronotype on motor skills specific to soccer, specifically whether agility, aerobic endurance, and explosive power differ among the three chronotypes in relation to the time of day. For this study 141 adolescent soccer players filled in the Morningness-Eveningness Questionnaire (MEQ) for the assessment of chronotype. A subsample of 75 subjects, subdivided in M-types (n= 25), E-types (n= 25), and N-types (n= 25), performed three tests (Sargent Jump Test - SJT, Illinois Agility Test - IAT, and 6-Minutes Run Test - 6MRT) at a morning and an evening training session (9:00 am and 6:00 pm). Mixed ANOVA was used to test the interactions between chronotypes, physical performance, and time. On all tests, better performance during the morning than the evening session was observed for the M-types ($p < .05$), whereas the E-types performed better in the evening than in the morning session ($p < .05$), and no differences in test performance were detected for the N-types. These findings underline the importance of a correct chronobiological approach to sports training. Scheduling training sessions according to an athlete's circadian preferences could be a valid strategy to enhance performance.

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Introduction

Human daily behavior besides physiological and psychological variables follows regular rhythms, with peaks and falls in activity and attention at specific times of day, month or year. The differential expression of circadian rhythms is a characteristic of inter-individual variability that can be expressed with the concept of chronotype or circadian typology, i.e. individual differences in time preference for morning or evening activities (Adan and Natale 2002; Montaruli et al. 2017b; Roveda et al. 2017). People can be typically classified into three chronotypes: Morning-types (M-types) who get up and go to bed early and usually perform better mentally and physically in the first part of the day; Evening-types (E-types) who get up and go to bed late and tend to plan their activities in the afternoon or evening; and

Neither-types (N-types) who fall somewhere between the other two (Adan et al. 2012; Montaruli et al. 2017a; Vitale et al. 2015).

Individual variations in circadian rhythms are determined by genetic (Kyriacou and Hastings 2010; Reppert 1995) and environmental factors (Carandente et al. 2006; Calogiuri et al. 2009; Di Iorio et al. 2012) that can contribute to variations in preference for time of day. The chronotype changes with age: eveningness in youth gives way to be more morning oriented in older age (Montaruli et al. 2017b). A progressive shift toward evening preference begins during adolescence, between age 12 and 13 years (Russo et al. 2007), stops at about 14 years, then gradually changes after age 18 (Crowley et al. 2014; Diaz-Morales and Sorroche 2008; Koscec Bjelajac et al. 2014; Randler 2008a; Roenneberg et al. 2004).

This tendency toward eveningness during adolescence implies misalignment with morning society schedules, leading to a deterioration in intellectual, motor, learning, social activities, and sleep (Enright and Refinetti 2017; Randler 2008b; Smith et al. 2013; Vitale et al. 2017a). The effect of chronotype on intellectual performance has been amply studied in high school and university students (Adan et al. 2012; Carrier and Monk 2000; Enright and Refinetti 2017; Goldstein et al. 2007; Montaruli et al. 2019; Randler 2017), but relatively few studies have investigated the relationship between chronotype and physiological variables or physical performance (Kuusmaa-Schildt et al. 2019; Vitale and Weydahl 2017b). Previous studies (Hill et al. 1988; Kunorozva et al. 2014; Rae et al. 2015; Rossi et al. 2015; Sugawara et al. 2001) have evaluated the effect of chronotype on variables such as heart rate (HR), rating of perceived exertion (RPE), and maximum oxygen consumption (VO_{2max}), while others investigated the relationship between chronotype and physical performance in untrained and trained subjects in diverse sports (Bonato et al. 2017a; Brown 2008; Burgoon et al. 1992; Facer-Childs and Brandstaetter 2015; Henst et al. 2015; Tamm 2009; Rahnama 2009; Reilly and Down 1986; Reilly et al. 2007a; Reilly and Edwards 2007b).

A significant effect of chronotype on HR recovery after a cycle ergometer test in the morning (Sugawara et al. 2001) was observed for E-types (higher HR values) than M-types. During a maximal ergometer test, higher VO_{2max} was recorded for E-types in the evening than in the morning test session, whereas M-types showed no differences (Hill et al. 1988). Also plantar-flexor maximum voluntary contraction measured in untrained adults in the evening session was greater among the E-types than the M-types (Tamm et al. 2009). RPE measured after a self-paced walking task was higher for the E-types than the M-types in the morning session (Rossi et al. 2015). Furthermore, in a sample of trained male cyclists (all M-types) the RPE score after a submaximal cycle test was higher in the evening than in the morning session (Kunorozva et al. 2014). Differently, the RPE score recorded in trained swimmers (M- and N-types) after a 200-meter

swim showed no interaction with chronotype (Rae et al. 2015).

Investigating the relationship between chronotype and physical performance, Brown et al. (2008) showed that the total time for a 2000-meter rowing sprint in a sample of rowers was better for the M-types in the morning session. In addition, in trained marathon runners, the race time of M-types was better than that clocked for N- and E-types early in the morning (Henst et al. 2015).

Few studies to date have evaluated the interaction between chronotype and motor skills specific to performance in team sports. In hockey players, Facer-Childs and Brandstaetter (2015), by means of a progressive aerobic endurance test, showed that the total execution time was better in M-types than in N- and E-types. Previous studies showed that performance parameters in soccer (e.g. reaction time, fatigue, flexibility, hand grip strength and soccer-specific skills like juggling) are affected by diurnal variations (Rahnama et al. 2009; Reilly et al. 2007a; Reilly and Down 1986; Reilly and Edwards 2007b). However, these studies did not compare differences in motor skills between the three chronotypes (Reilly 2007a) or only referred to intermediate chronotypes.

To date, little attention has been paid to the link between chronotype and motor skills in soccer, though it is one of the world's most popular sports practiced during adolescence and particularly by boys. Training and soccer matches are usually held after school in the afternoon or evening. Performance in soccer is related to a host of factors, including physiological variables and motor skills that have a circadian variation. Experimental evidences for chronotype differences have practical implications for soccer coaches, both in preparing the team depending on the time of the match and to optimize training programs. To the best of our knowledge, no studies have evaluated the interaction between chronotype, time of the day, and physical performance in adolescent soccer players.

The aim of this study was to evaluate the chronotype effect on motor skills specific to soccer and to determine whether agility, aerobic endurance, and explosive power differ among the three chronotypes in relation to the time of day.

Methods

Participants

Participants were recruited from four nonprofessional soccer teams. A total of 141 male soccer players (mean age 14.9 ± 1.79 yrs) were enrolled. Height and weight were recorded to calculate the body-mass index (BMI, weight in kilograms divided by height in meters square). All subjects were normal weight (mean BMI 20.2 ± 2.49). The Morningness-Eveningness Questionnaire (MEQ) (Horne and Östeberg 1976) was administered to categorize participants into three chronotypes: M-, N-, and E-types. The participants also completed the Pittsburgh Sleep Quality Index (PSQI) to evaluate subjective sleep quality.

Participants were asked to maintain their daily habits. Reasons for exclusion from the study were medical conditions diagnosed by a sports medicine physician that could affect physical performance. Signed written informed consent for participation was obtained from the parents. Before the beginning of the study, all participants, with his parents, received an explanation of the purpose, methods, risks, and benefits of the study.

The study was carried out in accordance with the tenets of the 1964 Declaration of Helsinki and approved by the Ethical Review Board of the University of Milan. The study protocol and procedures complied with the guidelines required by the journal (Portaluppi et al. 2010).

Measurements

Morningness-Eveningness Questionnaire (MEQ)

Diurnal preferences were assessed by the Morningness-Eveningness Questionnaire (MEQ). MEQ is a self-evaluation questionnaire developed by Horne and Östeberg (1976) to investigate preferred behavior. It is one of the most widely used questionnaires to evaluate circadian typology owing to its good stability (88–89), range of reliability coefficient (between 78 and 86) (Adan and Natale 2002; Adan et al. 2012), and translations and validation in multiple languages.

We opted for the validated MEQ Italian version (Mecacci and Zani 1983), which consists of 19 multiple choice items that investigate besides

sleep/wake habits, feelings and moods before retirement to bed or soon after waking up and rising, also the time of day at which subjects feel they perform better. The responses are scored from 0 to 6. The total score indicates the circadian typology (range 16 to 86), wherein a score from 16 to 41 indicates evening preference (E-types), differentiated in definite E-types (16–30) and moderate E-types (16–41), a score from 59 to 86 indicates morning preference (M-types), differentiated in definite M-types (70–86) and moderate M-types (59–69), finally a score from 42 to 58 indicates no particular morning or evening preference (N-types).

Based on their circadian characteristics, the 141 subjects were subdivided into M-types ($n=25$), N-types ($n=90$), and E-types ($n=26$). After completing the MEQ, 13 N-types and 1 E-type were unable to perform the physical tests for medical reasons. Since N-types were far more numerous than M-types or E-types, we created three numerically equivalent groups for the subsequent part of our analysis. Accordingly, a group of 25 subjects were categorized as N-types from among those with a MEQ score close to the mean of the range for N-types on the MEQ scale (range 42–58; mean=50). Subjects with MEQ scores at either end of the scale (42–43 and 57–58) were excluded (12% of the N-types). For the next phase of the study, we randomly selected 25 subjects from among the remaining 88% N-types and conflated the definite and moderate M-types and the definite and moderate E-types into two broad M- and E-type groups. In this way, we obtained a subsample of 75 soccer players, subdivided into M-, N-, and E-types.

Pittsburgh sleep quality index questionnaire (PSQI)

Each participant completed the Pittsburgh Sleep Quality Index (PSQI) to evaluate sleep quality. The PSQI is a retrospective, self-report questionnaire that evaluates sleep quality during the 30 days prior to compilation. It consists of 18 items that evaluate the total sleep quality and 7 sleep patterns, termed domains or components:

- (1) Perceived sleep quality (range from “very good” to “very bad”)

- (2) Sleep latency (time needed to fall asleep)
- (3) Sleep duration (hours spent asleep)
- (4) Sleep efficacy (number of hours slept)
- (5) Sleep disturbances, midnight awakening, toiletting, difficulty breathing, coughing, too cold/hot, pain, nightmare, snoring among others
- (6) Use of sleep medications (sleep inducers)
- (7) Daytime dysfunctions, difficulty in performing daily tasks

For the last three domains, respondents can self-report the causes of poor sleep and the effects of sleep debt: the number and the reasons for awakening during night and the frequency of difficulty in performing daily activities. The second and third components serve to calculate the minutes of sleep latency and total amount of sleep hours. Each response is assigned a score from 0 to 3, where 0 indicates no problem or good sleep and 3 indicates problems or poor sleep. Lower component grades indicate better sleep quality and less-disrupted sleep patterns. The total sum ranges between 0 and 21 and the final global score of 5 is the cutoff value differentiating good sleeper (0–5) from bad sleeper (6–21) (Buysse et al. 1989). Summarizing, a lower final score indicates a better quality of sleep. We administered the PSQI Italian version (Curcio et al. 2013), which has a proven internal consistency of 0.835 reliability coefficient (Cronbach α).

Physical tests

Three physical tests were used to investigate three different aspects that can influence sport performance: agility, aerobic endurance, and explosive power. The three tests were performed in two training sessions at 9:00 a.m. and at 6:00 p.m., respectively. The participants were randomly assigned to two groups scheduled at the two different times: group 1 (13 M-types, 13 N-types, 13 E-types) performed the tests first at 6:00 p.m. and then at 9:00 a.m., and group 2 (12 M-types, 12 N-types, 12 E-types) performed the tests at 9:00 a.m. and then at 6:00 p.m. The three tests were administered in random order on different days one week apart. During the three tests, both at 9:00 a.m. and 6:00 p.m., the same sports scientist supervised the performance and recorded the results. Figure 1 illustrates the study flowchart.

Sargent jump test

The Sargent Jump Test (SJT) is designed to evaluate explosive power of the lower limbs. Preparing for the test, subjects raise their arms against a wall and the highest point of the hands is marked on the wall and measured with a meter. This point indicates the starting position from which measurement are taken. Subjects jump from a standing position. They touch the wall to make a mark at the highest point of the jump. The highest score of three trials is recorded. The SJT score is obtained by subtracting the highest point measured to the starting point. The higher the score of the SJT, the better the performance.

Illinois agility test

The Illinois Agility Run Test (IAT) evaluates agility by measuring the ability to change direction quickly while controlling the movement of the whole body. The goal of the IAT is to run a course within the shortest time possible. The length of the course was 10 meters and the width (distance between the starting and the finishing line) 5 meters. Eight cones and a stopwatch were employed: four cones to mark the starting, the finishing, and the two turning points, the other four at the center spaced 3.3 meters apart. On the 'Go' command, the subjects ran the course as quickly as possible without knocking the cones over and returned to the finish line. The time was recorded with a stopwatch. The lower the score of the IAT, the better the performance.

6-minute run test

The 6-Minute Run Test (6-MRT) measures aerobic endurance and is a shorter alternative to the 12-minute Cooper run test. After a warm-up of 10–15 minutes of walking at medium-low intensity, the subjects ran at a constant speed as far as possible in 6 minutes. The score indicates the total distance covered in 6 minutes and is measured in meters. The higher the score of the 6-MRT, the better the performance.

Statistical analysis

For each circadian typology (M-, N- and E-type), we calculated the mean values and standard deviations of

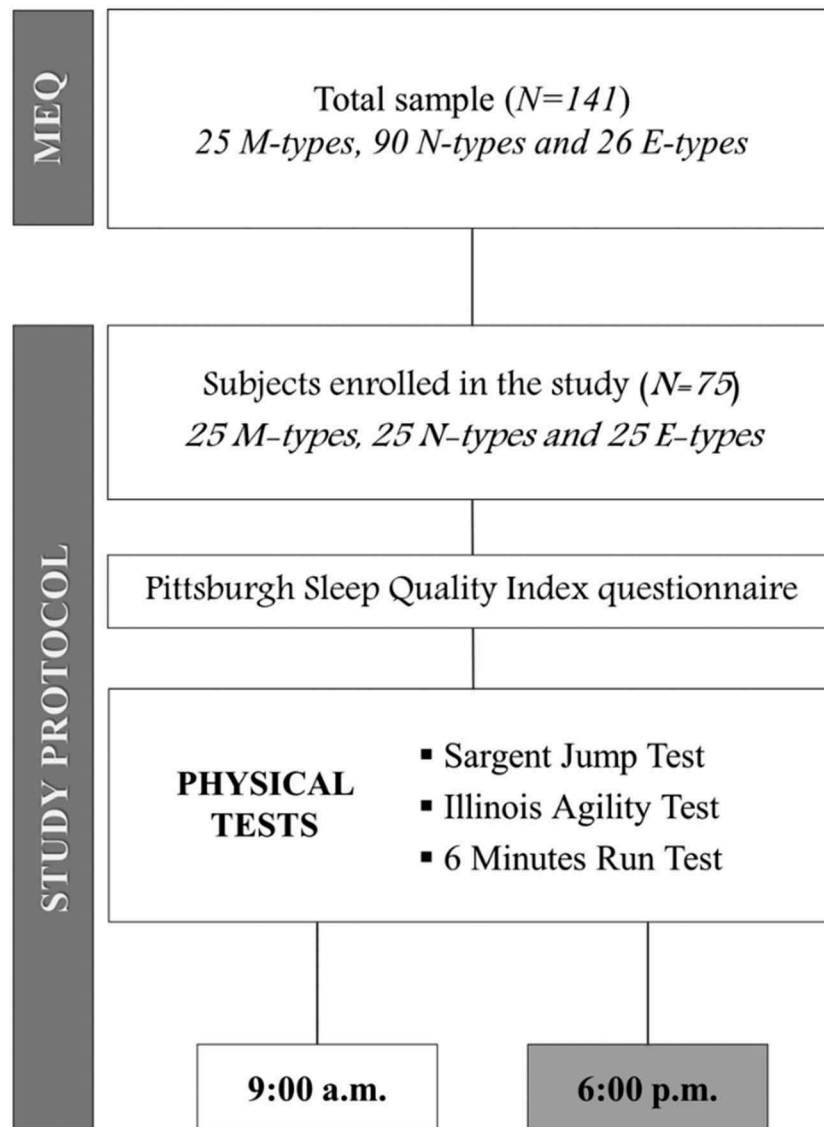


Figure 1. Study flowchart.

the results of the PSQI. The normality of the distribution of the PSQI data was assessed by graphical methods, as well as by Shapiro-Wilk test. The data were normally distributed. Thus, one-way ANOVA followed by pairwise post-hoc comparisons, if necessary, were performed to assess whether there was any difference in the mean PSQI values among the three chronotypes. For each circadian typology, we then calculated the mean values and standard deviations of the results of the three motor-skills tests (SJT, IAT and 6-MRT) recorded in the two training sessions (morning and evening). The normality of the distribution of the data was assessed by graphical methods, as well as by Shapiro-Wilk test. The data were normally

distributed with the exception of IAT in the M-types, in both training sessions. This was due to the presence of two subjects with elevated values of IAT, in both training sessions. We thus performed all the subsequent statistical analyses for the IAT either excluding or including these two subjects. Given that the results obtained removing these two subjects differed very little from those obtained with all of the subjects, only the latter results will be shown and discussed. The Levene's test was used to evaluate the homogeneity of variance of the data. The analysis of each physical test describing the motor skills of the young soccer players was carried out using the mixed ANOVA procedure. The results obtained in each test (i.e. SJT,

IAT and 6-MRT) were dependent on two factors: a between-subjects factor (i.e. the chronotype: M-, N- and E-type) and a within-subjects factor (i.e. the time of the day of the training session: morning and evening). The primary purpose of the mixed ANOVA was to establish if there was an interaction between the two factors, that is if the modality of change of the motor-skills test over time (from morning to evening) was dependent on the chronotype. When the interaction was statistically significant, this indicated that the impact of the chronotype on the motor-skills test depended on the level of time. This condition was visualized as when the three lines (one line per chronotype) connecting the levels of the motor-skills test measured at the two time points (morning and evening) were not parallel. To single out the individual effects of chronotype and time on the motor-skills test, we took into account whether the interaction was significant or not. A preliminary analysis showed that a significant interaction was present for all of the three motor-skills test. As a result, the simple main effect of chronotype was determined by testing for differences in the motor-skills parameter among the chronotypes at each level of time. Thus, for each motor-skills test, two separate one-way ANOVAs were performed, one for each of the two levels of time. When necessary, pairwise post-hoc comparisons tests were performed. The simple main effect of time was determined by testing for differences in the motor-skills test between the morning and the evening session for each chronotype. Thus, for each motor-skills test, three separate paired t-tests were performed, one for each chronotype. The strength of the effect of time on each motor-skills test within each chronotype was quantified by evaluating the effect size according to Cohen (Cohen 1992). We are aware that there is no straightforward way to interpret standardized effect size measures. Nevertheless, we report here the commonly used rule-of-thumb reference values for Cohen's *d* interpretation: $d < 0.2$ "negligible", $d < 0.5$ "small", $d < 0.8$ "medium", $d > 0.8$ "large". In all the

above-described analyses the statistical significance was set at $p < .05$. The statistical analyses were performed using either JMP version 14.0.0 (SAS Institute) or R version 3.5.3.

Results

Anthropometric characteristics of the subjects and Pittsburgh sleep quality index

Table 1 presents the anthropometric characteristics of the subsample of 75 subjects who underwent the physical tests. The mean PSQI score was, 3.2 ± 2.3 , 3.5 ± 1.7 , and 3.7 ± 2.0 for the M-, N-, and E-types, respectively. The one-way ANOVA analysis of PSQI showed no statistically significant difference between the three chronotypes.

Table 1. Anthropometric characteristics (mean \pm SD) of M-, N- and E-type soccer players performing the physical tests.

Anthropometric characteristics			
	M-TYPES (<i>n</i> = 25)	N- TYPES (<i>n</i> = 25)	E- TYPES (<i>n</i> = 25)
Body mass (kg)	55.8 \pm 11.0	59.1 \pm 13.0	62.2 \pm 11.3
Height (m)	1.7 \pm 0.1	1.7 \pm 0.1	1.7 \pm 0.1
BMI (kg/m ²)	20.1 \pm 2.4	19.6 \pm 2.8	21.0 \pm 2.2

Results of the physical tests

The results of the three motor-skills tests data are reported in Tables 2–4 and Figure 2. Table 2 reports the mean scores and standard deviations of the three motor-skills tests (i.e. SJT, IAT and 6-MRT) performed in the two sessions (i.e. in the morning at 9:00 a.m. and in the evening at 6:00 p.m.) by the three chronotypes (i.e. M-, N- and E-type). It can be appreciated that the scores for the M-types were better in the morning session than in the evening session. Quite to the contrary, the scores of the E-types were better in evening session than in the morning session.

Table 2. Mean scores and standard deviations for Sargent Jump Test (SJT), Illinois Agility Test (IAT), and 6-Minute Run Test (6-MRT), at 9:00 a.m and 6:00 p.m., in M-, N-, and E-types.

Physical tests						
	SJT (m) 9:00 a.m.	SJT (m) 6:00 p.m.	IAT (s)9:00 a.m.	IAT (s) 6:00 p.m.	6-MRT (m) 9:00 a.m.	6-MRT (m) 6:00 p.m.
M-Types	0.90 \pm 0.13	0.89 \pm 0.13	17.0 \pm 1.3	17.1 \pm 1.3	1277.6 \pm 156.9	1245.6 \pm 159.6
N-Types	0.88 \pm 0.09	0.88 \pm 0.09	16.9 \pm 0.8	16.9 \pm 0.8	1171.8 \pm 204	1188.1 \pm 205.9
E-Types	0.88 \pm 0.10	0.90 \pm 0.09	16.6 \pm 0.7	16.4 \pm 0.7	1220.3 \pm 150.8	1289.7 \pm 168.1

Table 3. Paired t-test used to compare the results obtained by M-, N-, and E-types at 9:00 a.m. and at 6:00 p.m.

	Sargent Jump Test 9:00 a.m. vs 6:00 p.m.	Illinois Agility Test 9:00 a.m. vs 6:00 p.m.	6 Minutes Run Test 9:00 a.m. vs 6:00 p.m.
M-Types	p= .017	p= .023	p= .026
N-Types	p= .303	p= .628	p= .158
E-Types	p= .034	p= .002	p= .00006

The panels of **Figure 2** (one panel for each motor-skills test) show the sample average responses for each chronotype (M/N/E) recorded in the two training sessions carried out in the morning and in the evening. The panels also report the results of the mixed ANOVA procedure indicating the presence of a strong significant interaction between the chronotype and the time of the day for all the three motor-skills tests.

The subsequent one-way ANOVAs conducted to assess the simple main effect of the chronotype showed no significant difference among the three chronotypes at each level of time for the three motor-skills tests. **Table 3** shows the results of the subsequent paired t tests conducted to assess the simple main effect of the time of the day. There was a statistically significant difference in the test scores on the morning SJT, IAT, and 6-MRT between the M-types and the E-types, whereas no statistically significant difference in the morning and evening test scores was observed for the N-types. Specifically, the M-types performed the best on the morning test, the E-types the best on the evening test, while the N-types performed virtually the same during the two training sessions.

Table 4 presents, for each of the three motor-skills tests and only for the M-types and E-types, the effect sizes of the change in performance between the morning and the evening training sessions. The effect size was medium on the SJT and small on the IAT and 6-MRT for the M-types,

whereas it was small on the SJT, medium on the IAT, and large on the 6-MRT for the E-types.

Discussion

The aim of the present study was to investigate the effect of chronotype on physical performance measured using the same tests at two different times of day (9:00 a.m. and 6:00 p.m.) in nonprofessional adolescent soccer players. Three of the essential motor skills in soccer are agility, aerobic endurance, and explosive power of the lower limbs, which we evaluated by means of three widely used tests (SJT, IAT, and 6-MRT). The main finding of this study was that chronotype was observed to affect agility, aerobic endurance, and explosive power: the M-types scored higher on the morning than the evening tests, whereas the E-types scored lower on the morning than on the evening tests. No chronotype effect on morning and evening test scores was observed for the N-types. The chronotype effect on motor skills does not seem to be influenced by sleep quality; indeed, the PSQI showed no differences between the three chronotypes. The chronobiological approach to sports, and to physical performance in particular, is a relatively recent field of interest. Some studies have focused on the effect of time of day on the technical skills specific to various sports (Atkinson et al. 2005; Carandente et al. 2006; Martin et al. 2007; Reilly et al. 2007a; Sedliak et al. 2007; Sinclair et al. 2013; Taylor et al. 2011; Thun et al. 2015), VO_{2max} capacity (Knaier et al. 2019), cortisol levels (Bonato et al. 2017b; McLellan et al. 2011), ratings of perceived exertion and mood (Vitale et al. 2017c). Most have reported that some aspects of physical performance improve between morning and afternoon or evening. Typical technical skills (e.g. in tennis and soccer) that involve fine motor control seem

Table 4. M- and E-types effect size values for each test.

Test	Effect Size	Performance
		9:00 a.m. vs 6:00 p.m.
M-Types		
Sargent Jump Test (m)	0.51	Worsened
Illinois Agility Test (s)	0.49	
6 Minute Run Test (m)	0.48	
E-Types		
Sargent Jump Test (m)	0.45	Improved
Illinois Agility Test (s)	0.71	
6 Minute Run Test (m)	0.97	

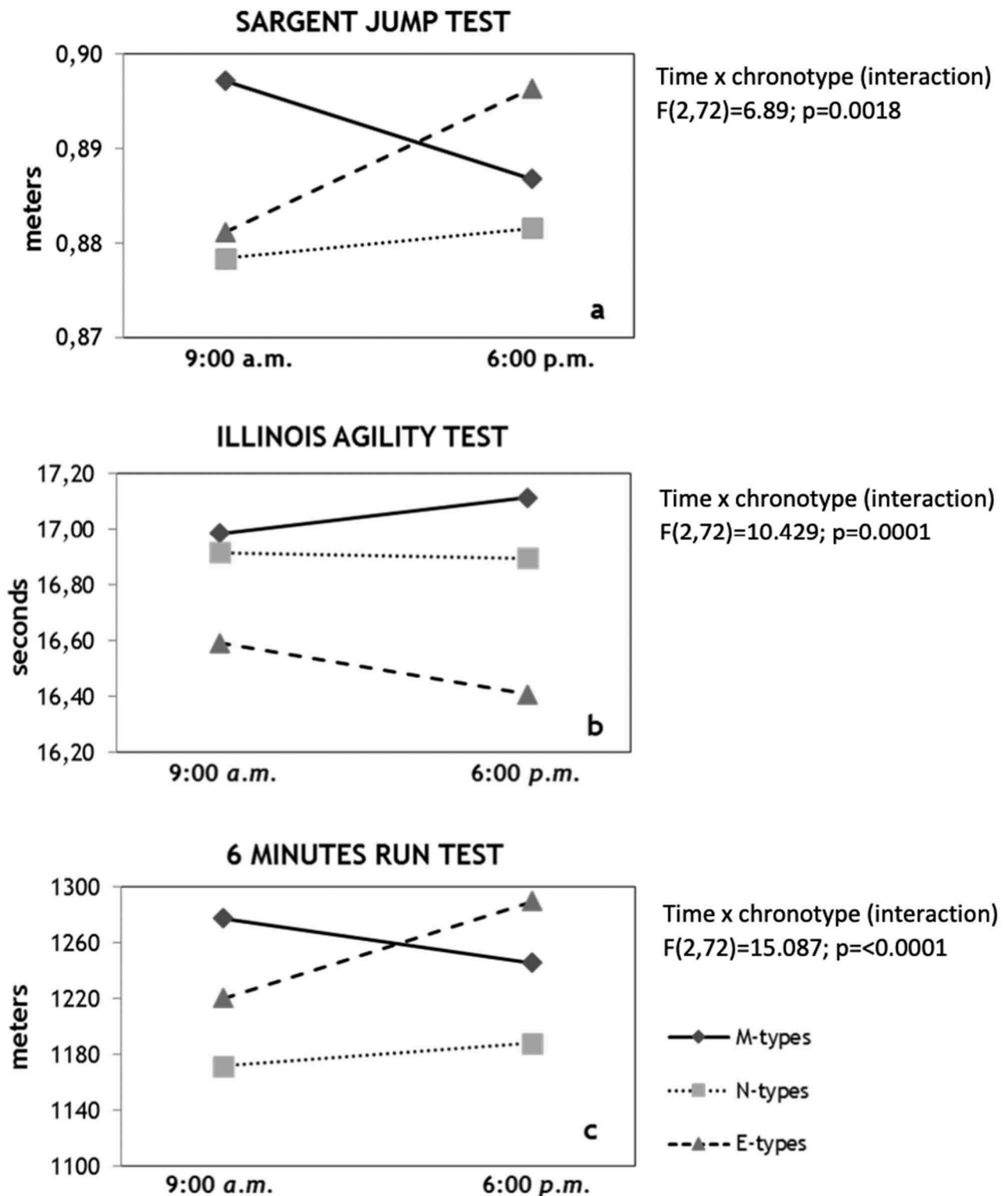


Figure 2. Mixed ANOVA, time x chronotype (interaction), for Sargent Jump Test (a), Illinois Agility Test (b), and 6 Minutes Run Test (c), performed in the morning (9:00 a.m.) and in the evening (6:00 p.m.) training sessions. M-, N-, and E-types are represented respectively by the continuous, broken and dotted line.

to have an acrophase somewhat earlier in the day than the peak in muscle strength and anaerobic performance, which seems to occur in the early evening (Thun et al. 2015).

Studies investigating specific soccer skills and physical factors in adult soccer players have reported that these factors are affected by time of day. Reilly et al. (2007a) reported that some specific skills and

physical performance were better in the evening. Also, Rahnama et al. (2009) found a significant effect of time of day on the SJT, right hip flexibility, and 20-m running, with better scores recorded in the evening. Also specific soccer skills, such as dribbling, wall volley, and soccer chipping, were noted to have a significant diurnal variation. In brief, we may assume that there are circadian rhythms in the performance of soccer players.

Few studies to date have investigated the relationship between chronotype and physical performance (Brown et al. 2008; Castelli et al. 2019; Henst et al. 2015; Mulè et al. 2019). There is general agreement that M-types tend to perform better in the morning than N- and E-types. For example, marathon runners with morning preference clocked faster race times compared to the other chronotypes when they ran in morning events (Henst et al. 2015). Also, on the 2000-m rowing sprint (Brown et al. 2008) and in the 200-m swimming trial (Rae et al. 2015) M-types outperformed N- and E-types when their training time was in the early half of the day.

Although soccer is the most widely practiced sport worldwide, very few studies to date have investigated the effect of chronotype on physical performance in soccer players and none compared soccer motor skills between the three chronotypes or only referred to intermediate subjects (Reilly et al. 2007a). Furthermore, no studies to date have evaluated the effect of chronotype on physical performance in a sample of adolescent soccer players.

Adolescence is a particularly interesting period for investigating circadian characteristics. The orientation toward morning or evening preferences varies with age: during adolescence the sleep-wake cycle tends to begin later in the day, with a clear shift toward eveningness from early school age to adolescence and a peak in eveningness at this stage of life. Adolescents are noted to stay up progressively later, sleep later in the morning, make up sleep debt on weekends, have irregular sleep-wake schedules and subjectively poor sleep (Adan et al. 2012; Montaruli et al. 2017b). In agreement with previous work (Adan et al. 2012; Vitale et al. 2015), also in our sample of adolescents the chronotype distribution showed an age-related shift toward eveningness preference.

Soccer is one of the most widely practiced sports among adolescents and players need

technical, tactical, and physical skills to succeed. In this context, adolescence is the stage of life in which these skills, when well trained, reach their peak of development.

For the present study three different performance indicators were evaluated: agility, aerobic endurance, and explosive power by means of three field tests (SJT, IAT, 6MRT). The M-types scored higher on all three tests when performed in the morning than in the evening session. These observations are shared by Brown et al. (2008) who reported an increase in total time of the 2000-m rowing sprint for M-types between the morning and the evening session. We found that the E-types had lower scores on the morning tests, with a small effect size for the SJT, medium for the IAT, and large for the 6MRT.

We found no significant differences in test scores for the N-types between morning and evening session. Another study (Vitale et al. 2018) investigated the sleep quality, daytime tiredness and sleepiness in response to a late-evening high intensity interval training (HIIT) session in N-type soccer players that habitually trained late in the day. The authors showed no differences in these parameters in the nights before and after the HIIT session. This shows N-types seem to be unaffected by the time effect.

In agreement with some studies that showed an effect of chronotype on performance in sports (Brown et al. 2008; Henst et al. 2015), our results highlighted an interaction between chronotype, training session time and test performance. This finding underlines the importance of a correct chronobiological approach to sports. Further studies are needed to assess the effect of chronotype on performance in various sports. For sports technicians, it could be very important to train specific skills to maximize performance, particularly during adolescence. Scheduling training sessions based on circadian preferences could be a valid strategy to enhance athletic performance.

Conflict of interest

The authors declare no conflicts of interest.

ORCID

E. Roveda  <http://orcid.org/0000-0003-2092-3999>

A. Mulè  <http://orcid.org/0000-0002-2324-6375>

L. Galasso  <http://orcid.org/0000-0002-5344-4014>
 L. Castelli  <http://orcid.org/0000-0002-7701-9733>
 R. Scurati  <http://orcid.org/0000-0003-3247-1977>
 F. Esposito  <http://orcid.org/0000-0002-4420-2611>
 A. Caumo  <http://orcid.org/0000-0002-2507-0780>
 A. Montaruli  <http://orcid.org/0000-0003-4296-066X>

References

- Adan A, Archer SN, Hidalgo MP, Di Milia L, Natale V, Randler C. 2012. Circadian typology: a comprehensive review. *Chronobiol Int.* 29(9):1153–1175. doi:10.3109/07420528.2012.719971. PMID:23004349.
- Adan A, Natale V. 2002. Gender differences in morningness-eveningness preference. *Chronobiol Int.* 19(4):709–720. doi:10.1081/CBI-120005390. PMID:12182498.
- Atkinson G, Todd G, Reilly T, Waterhouse J. 2005. Diurnal variation in cycling performance: influence of warm-up. *J Sport Sci.* 23(3):321–329. doi:10.1080/02640410410001729919. PMID:15966350.
- Bonato M, Agnello L, Galasso L, Montaruli A, Roveda E, Merati G, La Torre A, Vitale JA. 2017a. Acute modification of cardiac autonomic function of high-intensity interval training in collegiate male soccer players with different chronotype: A crossover study. *J Sports Sci Med.* 16(2):286–294. PMID:28630583. PMCID:PMC5465992.
- Bonato M, La Torre A, Saresella M, Marventano I, Merati G, Vitale JA. 2017b. Salivary cortisol concentration after high-intensity interval exercise: time of day and chronotype effect. *Chronobiol Int.* 34(6):698–707. doi:10.1080/07420528.2017.1311336. PMID:28409690
- Brown FM, Neft EE, LaJambe CM. 2008. Collegiate rowing crew performance varies by morningness–eveningness. *J Strength Cond Res.* 22(6):1894–1900. doi:10.1519/JSC.0b013e318187534c. PMID:18978619
- Burgoon PW, Holland GJ, Loy SF, Vincent WJ. 1992. A comparison of morning and evening ‘types’ during maximum exercises. *J Appl Sport Sci Res.* 6(2):115–119.
- Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. 1989. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res.* 28(2):193–213. doi:10.1016/0165-1781(89)90047-4. PMID:2748771.
- Calogiuri G, Beldo S, Roveda E, Montaruli A, Carandente F, Weydahl A. 2009. Training time and adaptation to lack of daylight: A case report. *Sport Sci Health.* 5:37–41. doi:10.1007/s11332-009-0074-x.
- Carandente F, Montaruli A, Roveda E, Calogiuri G, Michielon G, La Torre A. 2006. Morning or evening training: effect on heart rate circadian rhythm. *Sport Sci Health.* 1(3):113–117. doi:10.1007/s11332-006-0020-0.
- Carrier J, Monk TH. 2000. Circadian rhythms of performance: new trends. *Chronobiol Int.* 17(6):719–732. doi:10.1081/CBI-100102108. PMID:11128289.
- Castelli L, Galasso L, Mulè A, Bruno E, Shokohyar S, Esposito F, Montaruli A, Roveda E. 2019. Physical activity, chronotype and sleep in a sample of Italian elderly population. *Sport Sci Health.* Article in press. doi:10.1007/s11332-019-00573-x.
- Cohen J. 1992. A power primer. *Psychol Bull.* 112:155–159. doi:10.1037//0033-2909.112.1.155. PMID:19565683.
- Crowley SJ, Van Reen E, LeBourgeois MK, Acebo C, Tarokh L, Seifer R, Barker DH, Carskadon MA. 2014. A longitudinal assessment of sleep timing, circadian phase, and phase angle of entrainment across human adolescence. *PLoS One.* 9(11):e112199. doi:10.1371/journal.pone.0112199. PMID:25380248. PMCID: PMC4224451.
- Curcio G, Tempesta D, Scarlata S, Marzano C, Moroni F, Rossini PM, Ferrara M, De Gennaro L. 2013. Validity of the Italian version of the Pittsburgh Sleep Quality Index (PSQI). *Neurol Sci.* 34(4):511–519. doi:10.1007/s10072-012-1085-y. PMID:22526760
- Di Iorio F, Cesarelli M, Bifulco P, Fratini A, Roveda E, Ruffo M. 2012. The effect of whole body vibration on oxygen uptake and electromyographic signal of the rectus femoris muscle during static and dynamic squat. *J Exercise Physiol Online.* 15(5):18–31.
- Díaz-Morales JF, Sorroche MG. 2008. Morningness-eveningness in adolescents. *Spanish J Psychol.* 11:201–206. doi:10.1017/S1138741600004248.
- Enright T, Refinetti R. 2017. Chronotype, class times, and academic achievement of university students. *Chronobiol Int.* 34(4):445–450. doi:10.1080/07420528.2017.1281287. PMID: 28272914.
- Facer-Childs E, Brandstaetter R. 2015. The impact of circadian phenotype and time since awakening on diurnal performance in athletes. *Curr Biol.* 25(4):518–522. doi:10.1016/j.cub.2014.12.036. PMID:25639241.
- Goldstein D, Hahn CS, Hasher L, Wiprzycka UJ, Zelazo PD. 2007. Time of day, intellectual performance, and behavioral problems in morning versus evening type adolescents: is there a synchrony effect? *Personality Individual Diff.* 42(3):431–440. doi:10.1016/j.paid.2006.07.008. PMID:17268574. PMCID:PMC1761650.
- Henst RH, Jaspers RT, Roden LC, Rae DE. 2015. A chronotype comparison of South African and Dutch marathon runners: the role of scheduled race start times and effects on performance. *Chronobiol Int.* 32(6):858–868. doi:10.3109/07420528.2015.1048870. PMID:26102236.
- Hill DW, Cureton KJ, Collins MA, Grisham SC. 1988. Diurnal variations in responses to exercise of morning types and evening types. *J Sports Med Phys Fitness.* 28(3):213–219. PMID:3230901.
- Horne JA, Östeberg O. 1976. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *Int J Chronobiol.* 4(2):97–110. PMID:1027738.
- Knaier R, Infanger D, Niemeyer M, Cajochen C, Schmidt-Trucksäss A. 2019. In athletes, the diurnal variations in maximum oxygen uptake are more than twice as large as the day-to-day variations. *Front Physiol.* 10:219. doi:10.3389/fphys.2019.00219.
- Koscec Bjelajac A, Rodosevic-Vidacek B, Bakotic M. 2014. Morningness-eveningness and sleep patterns of

- adolescents attending school in two rotating shifts. *Chronobiol Int.* 31(1):52–63. doi:10.24869/spsih.2018.3.
- Kunorozva L, Roden LC, Rae DE. 2014. Perception of effort in morning-type cyclists is lower when exercising in the morning. *J Sports Sci.* 32(10):917–925. doi:10.1080/02640414.2013.873139.
- Kuusmaa-Schildt M, Liukkonen J, Vuong MK, Nyman K, Hakkinen K, Hakkinen A. 2019. Effect of morning vs. evening combined strength and endurance training on physical performance, sleep and well-being. *Chronobiol Int.* 36(6):811–825. doi:10.1080/07420528.2019.1592184.
- Kyriacou CP, Hastings MH. 2010. Circadian clocks: genes, sleep, and cognition. *Trends Cogn. Sci.* 14(6):259–267. doi:10.1016/j.tics.2010.03.007. PMID: 20418150.
- Mah CD, Mah KE, Kezirian EJ, Dement WC. 2011. The effects of sleep extension on the athletic performance of collegiate basketball players. *Sleep.* 34(7):943–950. doi:10.5665/SLEEP.1132.
- Martin L, Nevill AM, Thompson K. 2007. Diurnal variation in swim performance remains, irrespective of training once or twice daily. *Int J Sports Physiol Perform.* 2(2):192–200. doi:10.1123/ijsp.2.2.192. PMID:19124906.
- McLellan CP, Lovell DI, Gass GC. 2011. Markers of post-match fatigue in professional Rugby league players. *J Strength Cond Res.* 25(4):1030–1039. doi:10.1519/JSC.0b013e3181cc22cc. PMID:20703169
- Mecacci L, Zani A. 1983. Morningness–eveningness preferences and sleep–waking diary data of morning and evening types in student and worker samples. *Ergon.* 26(12):1147–1153. doi:10.1080/00140138308963450. PMID:6686817.
- Montaruli A, Castelli L, Galasso L, Mulè A, Bruno E, Esposito F, Caumo A, Roveda E. 2019. Effect of chronotype on academic achievement in a sample of Italian university students. *Chronobiol Int.* 36:1482–1495. doi:10.1080/07420528.2019.1652831.
- Montaruli A, Galasso L, Carandente F, Vitale J, Roveda E, Caumo A. 2017a. If the Morning-Evening Questionnaire (MEQ) is able to predict the actigraphy-based acrophase, how does its reduced, five-item version (rMEQ) perform? *Chronobiol Int.* 34(4):443–444. doi:10.1080/07420528.2017.1306708.
- Montaruli A, Galasso L, Caumo A, Cè E, Pesenti C, Roveda E, Esposito F. 2017b. The circadian typology: the role of physical activity and melatonin. *Sport Sci Health.* 13(3):469–476. doi:10.1007/s11332-017-0389-y.
- Mulè A, Galasso L, Castelli L, Condemi V, Bisconti A, Esposito F, Roveda E, Montaruli A. 2019. Effect of chronotype on rating of perceived exertion in active young people. *Sport Sci Health.* Article in press. doi:10.1007/s11332-019-00610-9.
- Portaluppi F, Smolensky MH, Toitou Y. 2010. Ethics and methods for biological rhythm research on animals and human beings. *Chronobiol Int.* 27(9–10):1911–1929. doi:10.3109/07420528.2010.516381. PMID:20969531
- Rae DE, Stephenson KJ, Roden LC. 2015. Factors to consider when assessing diurnal variation in sports performance: the influence of chronotype and habitual training time-of-day. *Eur J Appl Physiol.* 115(6):1339–1349. doi:10.1007/s00421-015-3109-9. PMID:25631930.
- Rahnama N, Sajjadi N, Bambaiechi E, Sadeghipour H, Daneshjoo H, Nazary B. 2009. Diurnal variation on the performance of soccer- specific skills. *World J Sport Sci.* 2(1):27–30. ISSN 2078-4724.
- Randler C. 2008a. Morningness-eveningness comparison in adolescents from different countries around the world. *Chronobiol Int.* 25(6):1017–1028. doi:10.1080/07420520802551519.
- Randler C. 2008b. Differences between smokers and nonsmokers in morningness-eveningness. *Soc Behav Personality.* 36(5):673–680. doi:10.2224/sbp.2008.36.5.673.
- Randler C. 2017. Chronotype correlates with developmental index, intelligence and academic achievement: A study based on nationwide indicators. *Chronobiol Int.* 34(7):985–992. doi:10.1080/07420528.2017.1332070. PMID:28594245.
- Reilly T, Atkinson G, Edwards B, Waterhouse J, Farrelly K, Fairhurst E. 2007a. Diurnal variation in temperature, mental and physical performance, and tasks specifically related to football (soccer). *Chronobiol Int.* 24(3):507–519. doi:10.1080/07420520701420709. PMID:17612948.
- Reilly T, Down A. 1986. Circadian variation in the standing broad jump. *Percept Mot Skills.* 62(3):830. doi:10.2466/pms.1986.62.3.830.
- Reilly T, Edwards B. 2007b. Altered sleep–wake cycles and physical performance in athletes. *Physiol Behav.* 90(2–3):274–284. doi:10.1016/j.physbeh.2006.09.017. PMID:17067642.
- Reppert SM. 1995. Interaction between the circadian clocks of mother and fetus. *Ciba Found Symp.* 183:198–207. doi:10.1002/9780470514597.ch11. PMID:7656686.
- Roenneberg T, Kuehnle T, Pramstaller PP, Ricken J, Havel M, Guth A, Mrosovsky M. 2004. A marker for the end of adolescence. *Curr Biol.* 14(24):R1038–R1039. doi:10.1016/j.cub.2004.11.039. PMID:15620633
- Rossi A, Formenti D, Vitale JA, Calogiuri G, Weydahl A. 2015. The effect of chronotype on psychophysiological responses during aerobic self-paced exercises. *Percept Motor Skills.* 121(3):840–855. doi:10.2466/27.29.PMS.121c28x1.
- Roveda E, Vitale JA, Montaruli A, Galasso L, Carandente F, Caumo A. 2017. Predicting the actigraphy-based acrophase using the Morningness–Eveningness Questionnaire (MEQ) in college students of North Italy. *Chronobiol Int.* 34(5):551–562. doi:10.1080/07420528.2016.1276928. PMID:28276851.
- Russo PM, Bruni O, Lucidi F, Ferri R. 2007. Sleep habits in Italian children and adolescents. *J Sleep Res.* 16(2):163–169. doi:10.1111/j.1365-2869.2007.00584.x. PMID:17542946.
- Sedliak M, Finni T, Cheng S, Kraemer WJ, Hakkinen K. 2007. Effect of time-of-day-specific strength training on serum hormone concentrations and isometric strength in men. *Chronobiol Int.* 24(6):1159–1177. doi:10.1080/07420520701800686. PMID:18075805
- Sinclair J, Wright J, Hurst H, Taylor P, Atkins S. 2013. The influence of circadian rhythms on peak isokinetic force of quadriceps and hamstring muscles. *Isokinet Exerc Sci.* 21(4):279–284. doi:10.3233/IES-130498.

- Smith RS, Efron B, Mah CD, Malhotra A. 2013. The impact of circadian misalignment on athletic performance in professional football players. *Sleep*. 36(12):1999–2001. doi:10.5665/sleep.3248. PMID:24293776. PMCID:PMC3825451.
- Sugawara J, Hamada Y, Nishijima T, Matsuda M. 2001. Diurnal variations of post-exercise parasympathetic nervous reactivation in different chronotypes. *Jpn Heart J*. 42(2):163–171. doi:10.1536/jhj.42.163. PMID: 11384077.
- Tamm AS, Lagerquist O, Ley AL, Collins DF. 2009. Chronotype influences diurnal variations in the excitability of the human motor cortex and the ability to generate torque during a maximal voluntary contraction. *J Biol Rhythms*. 24(3):211–224. doi:10.1177/0748730409334135. PMID:19465698.
- Taylor K, Cronin J, Gill N, Chapman D, Sheppard J. 2011. Warm-up affects diurnal variation in power output. *Int J Sports Med*. 32(3):185–189. doi:10.1055/s-0030-1268437. PMID:21305444.
- Thun E, Bjorvatn B, Flo E, Harris A, Pallesen S. 2015. Sleep, circadian rhythms, and athletic performance. *Sleep Med Rev*. 23:1–9. DOI:10.1016/j.smrv.2014.11.003. PMID: 25645125.
- Vitale JA, Banfi G, La Torre A, Bonato M. 6 2018. Effect of a habitual late-evening physical task on sleep quality in neither-type soccer players. *Front Physiol*. 9:1582. doi:10.3389/fphys.2018.01582.
- Vitale JA, La Torre A, Baldassarre R, Piacentini MF, Bonato M. 2017c. Ratings of perceived exertion and self-reported mood state in response to high intensity interval training. a crossover study on the effect of chronotype. *Front Psychol*. 8:1232. doi:10.3389/fpsyg.2017.01232.
- Vitale JA, Montaruli A, Michielon G, Scurati R, Alberti G, Caumo A, Carandente F, Roveda E. 2017a. Sleep quality and cytokine expression after an exhaustive exercise: influence of ACE polymorphism I/D. *Sleep Biol Rhythm*. 15(1):31–37. doi:10.1007/s41105-016-0077-3.
- Vitale JA, Roveda E, Montaruli A, Galasso L, Weydahl A, Caumo A, Carandente F. 2015. Chronotype influences activity circadian rhythm and sleep: differences in sleep quality between weekdays and weekend. *Chronobiol Int*. 32(3):405–415. doi:10.3109/07420528.2014.986273. PMID:25469597
- Vitale JA, Weydahl A. 2017b. Chronotype, physical activity and sport performance: a systematic review. *Sports Med*. 47:1859–1868. doi:10.1007/s40279-017-0741-z. PMID:28493061.