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REVIEW

Circadian rhythm effect on military physical fitness and field training: a narrative review

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Abstract

Background Disruption of the circadian rhythm also has significant influences on the exercise function. Therefore, the aim of this study was to review the effects of circadian rhythm on physical fitness and athletic performance in military personnel.
Methodology An online search was done in web of science (WoS), Ovid, Scopus and PubMed (MeSH) databases with the following combination of keywords: "chronobiology" AND "performance of military" AND "exercise".
Results A total of articles were identified, physical fitness and sport performance of military forces is severely affected by the science of chronobiology and 24-h circadian rhythm. In humans, these articles showed circadian rhythm with affects on performance of various organs in the body, such that the body temperature, heart rate, hormonal secretion, electrolyte excretion, blood pressure, plasma tyrosine concentrations, free amino acids, cholesterol production and even behavior can affect physical fitness and athletic performance in the military force.
Conclusions Based on the analyzed articles, it is concluded that circadian rhythm has a significant effect on exercise performance, aerobic and anaerobic power, muscular endurance and flexibility, and hormonal secretion. For this reason, it is recommended to the organizers of the competitions and coaches should take into consideration the effects of circadian rhythm on the athletic performance of the military, the scheduling of competitions and exercises.

Keywords Chronobiology · Circadian rhythm · Military forces · Physical fitness · Exercise performance

Introduction

One of the essential factors for the military personnel in each country is having high level in physical fitness and exercise performance, especially in sport fields [1]. Therefore, the main goal of physical fitness in individuals is to improve the practical capabilities of military athletes to reach the peak of performance and position on the championship platform [2]. Physical fitness includes intrinsic and acquired characteristics and is associated with factors such as muscle strength, muscular power, muscular endurance, and cardio respiratory endurance [3]. Given that the military forces play a crucial role in defending the borders and preserving territorial integrity, they have to reach the desired level of physical fitness to carry out these missions through the daily use of bodybuilding exercises and combinations of exercises that enhance their physical skills including strength and endurance [1]. Generally, physical fitness in a military personnel involves having physical health, having the ability to carry out skilled and continuous movements, the ability to recover quickly after a lot of pressure, completing tasks and assignments, and having confidence in any situation [4, 5]. Because the military forces must have the best physical performance in different weather conditions, therefore, special attention should be paid to various factors affecting the level of physical fitness in different condition. Including the most important of these factors or condition is the circadian rhythm or chronobiology.

Also, It is stated that most military personnel are exposed to a long period of sleep deprivation due to special circumstances. Sleep disorders can affect physical health and performance. Sleep deprivation appears to have the greatest

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negative impact on aerobic capacity [6], muscle endurance, and specific military performance in the military population. Sleep deprivation reduces body strength. Since physical function plays an important role in the military forces, more attention should be paid to circadian rhythm disorders (especially limited sleep in military forces) [7]. The science of chronobiology can be used to determine the effects of time on physiological variables or the study of rhythmic patterns in biological phenomena [8]. The influence of the science of chronobiology or biological hours on physiological conditions and physical activity has been proven by previous studies [9, 10].

An individual's predisposition towards the different time of the day (morning or evening), commonly termed one's chronotype, can be grouped into either early chronotypes (ECT), late chronotypes (LCT) or those in between (intermediate chronotypes) [11]. The effect of circadian rhythms on exercise performance is well sttudied, and there is research to suggest that the rhythmicity of physiological and behavioral processes is correlated with maximum performance times. Most of studies suggests that optimal athletic performance occurs in the late afternoon-early evening, coinciding with the peak of core body temperature (CBT acrophase; 16:00–18:00) [12]. However, it is stated that the performance to be impaired when CBT is at its lowest (CBT nadir; 03:00) [13]. It has been show that higher core body temperature facilitate actin-myosin cross bridging in skeletal muscle and thus is thought to be associated with enhanced exercise performance [14]. Also studies show that muscular strength, independent of the muscle group or contraction speed, peaks in the late afternoon/early evening. Similar peaks have also been reported for anaerobic exercise and short-term power [15].

Disruption of the circadian rhythm also has significant influences on the exercise function. The circadian gene CLOCK mutation in mice results in significantly reductions in muscle power and exercise endurance. Studies have argued that the human body has special abilities during the day and experiences many changes [16]. Biological rhythms are called circadian rhythms that are repeated regularly and at specific times [17]. In addition, circadian rhythms refer to changes that alternate over a 24-h period [16]. Hostelry changes are attributed to "biological or biological hours (biological clock) that coordinates a variety of hostelry rhythms and plays a role in many physiological functions and is located in the superchiasmatic nucleus of the anterior hypothalamus [18]. Melatonin as a normal neurotransmitter secreted from the pineal gland, plays a vital role in regulating body hours and plays this role in a wide range of biological and physiological settings; it is effective in regulating biorhythms and circadian rhythms and maintaining these biological times. Another role is helping to renovate the cells and the immune system [19]. Shirvani et al., Showed that changes in some of the components of the humoral immune system including immunoglobulins and the complement system in response to exercise training may be affected by the circadian clock [20–22]. However, in this study we first examine the definitions as well as the exact physiological effects of circadian rhythms on the human body and then we consider the effects of circadian rhythms on exercise performance spatially in military forces.

Circadian rhythms

As previously stated the human body is composed of a rhythm and inner track that is famous on circadian rhythms. These rhythms have a 24-h cycle and have an impact on the functioning of the organs of the body. These rhythms are improved on a daily basis with the course of animal activity conditional. For instance, Jet lag is a physiological condition that results from alterations to the body's circadian rhythms caused by rapid long-distance trans-meridian (east–west or west–east) travel. It was long axiomatic that rods and cones are the only mammalian photoreceptors. Light hyperpolarizes these neurons, and the light signals propagate through the retinal circuitry to modulate spike firing in the retinal ganglion cells (RGCs). The RGCs send the light information to the brain via their axons, which constitute the optic nerve [23].

The most important factor contributing to the regulation of circadian rhythms is light, which is transmitted through the eyes to the brain, and for the relay and regulation of these rhythms, the superchiasmatic nucleus located in the hypothalamus is involved [24]. Figure 1 illustrates the events that occur in cerebral and peripheral tissues with circadian rhythms (Fig. 1). There are various definitions and divisions regarding circadian rhythms, some of which are introduce in below.

Endogenous rhythms

Endogenous rhythms are the rhythms that originate from the internal organ. For instance, environmental factors have no effect on the heartbeat that originates from the sinoatrial (SA) node [25]. These rhythms are used for 24 h and they are in the form of a distinct biological rhythm. Swirling fast (Ultradian) and slow down (inferadian) are two examples of rhythms that are longer than 24 h a day. Seasonal disorders in the reproductive system and menstrual cycle from the rhythms of inferadian and regular secretion of the pituitary gland hormones are examples of its Ultradian rhythms.

Exogenous rhythms

Exogenous rhythms occur if the appearance of the rhythms is due to external factors and the substance is consumed regularly and periodically [25].

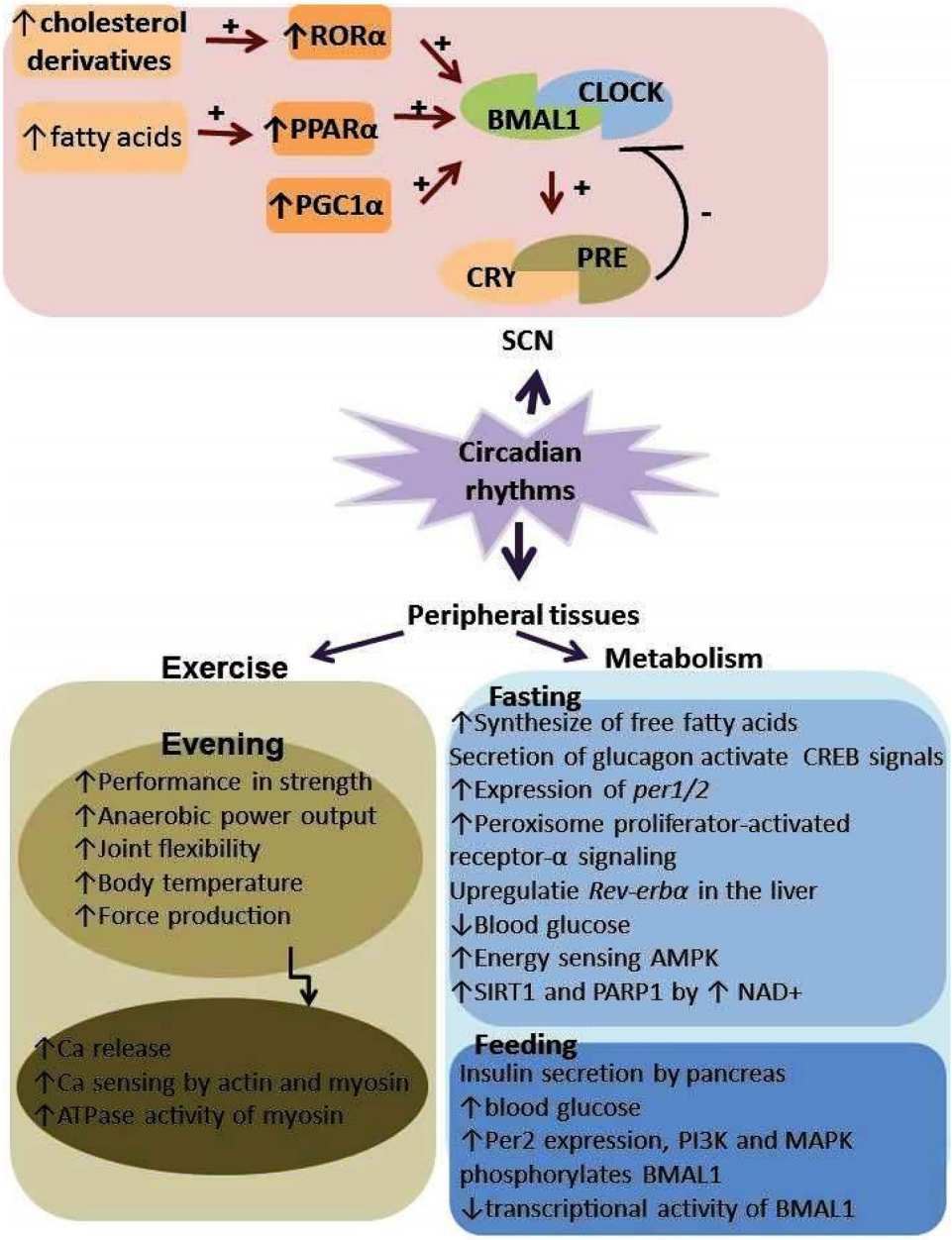

Fig. 1 Schematic view of alterations in circadian rhythms induced by light, exercise and nutrition

Slow down (inferadian rhythms)

Cycles that last longer than 24 h, such as regular monthly changes and secretions of female sex hormones and changes in the female genital area, which is repeated every 28 days, is an inferadian rhythm.

Swirling fast (ultradian rhythms)

There is a wide range of its Swirling fast rhythms in humans, whose range is like a neuronal message less than a second, like breathing in minutes, like a sleep cycle and awakening within an hour. It should be noted that its Ultradian rhythm is much faster than daily rhythm. For example, in the secretion of hormones, there are usually 4–8 mutations within 24 h, some of which occur at certain hours in close proximity and in certain hours, so it is believed that the fast-moving tracks are the basis of the daily utterance. The most famous song is the Ultradian cycle, which includes a period in sleep [25].

Different effects of circadian rhythms on the body

Sleep and awakening

Sleep and awakening are the most important body rhythms that routinely lead people from the state of consciousness to

unconsciousness and vice versa. As the age increases, the cells of the center of the body's stimulation are destroyed and change the rhythm of the day. This condition causes a lot of sleep, sleep disturbances and rapid waking up of sleep. Your circadian rhythm causes your level of wakefulness to rise and dip throughout the day. Most people feel the strongest desire to sleep between 1:00 p.m. and 3:00 p.m. (a.k.a. the post-lunch, afternoon crash) and then again between 2:00 a.m. and 4:00 a.m., but this can vary from person to person. That's why some people are "morning people", while others function best in the evening. Your circadian rhythm can also change as you age. When you were a teenager, for example, your body was programmed (so to speak) to sleep for more total hours, as well as go to bed and wake up later. If you follow your body's natural cues regarding when to go to sleep and wake up, your circadian rhythm should stay balanced, but a change in your schedule (like if you stay up late pulling long hours at work one day or sleep in one Saturday), can disrupt your body clock.

Regulating body temperature

Body temperature reaches maximum after 18 h and decreases regularly during inactivity. We usually see an increase in body temperature before and after awakening. The light increases the range and decreases the degree of heat when the cycle of the skin increases and the body loses a lot of heat. According to the principle of life balance, body temperature is regulated by receptors of different parts of the body and by the dorsal nuclei of the hypothalamus.

Endocrine cycle

Overall, all hormones are regulated to a degree by circadian rhythm. The concentration of corticosteroids is regulated by the cycle of light-darkness and sleep and awakening. This cycle is also influenced by external factors (such as the body temperature cycle). This cycle normally takes about 24 h in humans, given that the corticotrophin hormone cycle disappears after the damage of superchiasmatic nucleus (SCN). The adrenal gland hypertrophy appears to be affected by the hypothalamic midline abdominal nuclei, so that the damage of the SCN does not result in stopping the cycle [25].

Blood pressure

The blood pressure of people varies in different times of the day, such that any change in blood pressure has important meanings in the diagnosis, control and treatment of hypertensive patients. In general, blood pressure rises rapidly in the early hours of the morning in people with hypertension and those with normal blood pressure. This system is affected by genetics, and when a person wakes up, her blood pressure starts to rise automatically. The increase in blood pressure, which is associated with increased heart rate, responds to the following biological changes, which are also affected by day-to-day rhythms: A. Increased catecholamine's, especially norepinephrine, in the bloodstream. B: Increased plasma renin activity reaches peak blood pressure at the end of the morning and early afternoon, and after that, blood pressure decreases and falls to the lowest level at 8 p.m. and 2 a.m.

Biological rhythm and pain

The researchers conducted precise experiments in relation to pain sensation on the hands and teeth, and the results indicate that the maximum pain threshold is between 12–18 h and the minimum threshold is between 0 and 3 a.m. Pain relievers are less effective in reducing pain in the night, because the sensitivity of pain at night increases. In addition, athletes who work late in the day are better at work, as pain tolerance is more likely at the end of the day. The result shows that the most pain tolerance usually occurs in the afternoon [26].

Molecular mechanism in SCN

In line with King et al., discovery in 1997, the molecular mechanism of circadian rhythm is adjusted by CLOCK system. This molecular system contains several main elements including brain and muscle ARNT-Like 1 (BMAL1), CLOCK, Cryptochromes (CRY1, CRY2) and period circadian regulator 1 (PER1)/PER2. Most of them are transcription factors regulating gene expression. Firstly, BMAL1 and CLOCK form heterodimer and bind to E-box located on the promoter of two genes, Cry and Pre and induce their expression [27]. After transferring to the cytoplasm, the PER/CRY/ Casein kinase 1ε (CK1ε) complex is formed which returns to the nucleus and affect the negative feedback on the expression of Per and Cry and suppresses the expression of BMAL1/CLOCK heterodimer. PER and CRY are degraded via ubiquitination system. In addition to PER and CRY, REVs-ERBs and RORs are other proteins that their transcriptions are regulated by BMAL1/CLOCK heterodimer. REVs- ERBs has an inhibitory role on the expression of BMAL1 and CLOCK genes while the ROR is the activator element for both genes [28]. Recently, it was reported that the expression of CLOCK gene in other tissues such as liver, skeletal muscle and bone could involve specific rhythmic functions and homeostasis in each tissues [29].

Disruption of circadian rhythms

Signs and symptoms of disruption of circadian rhythms include: (I) sleep disorder, (II) short-term fatigue, (III)

sickness, (IV) anorexia, and (V) change beliefs. The most important disorder of the cycles of sleep disorders and depression is related to the change in the working hours of people. Disturbances caused by changes in working hours are as a result of delay in the onset of radiation. In this disorder, some physiological factors like heart rate, epinephrine and norepinephrine hormones are secreted with the cycle [30]. If others can adapt for days or weeks, the ability of individuals to work in different shifts is different. A large number of these people suffer the least damage or suffer from problems, but some cannot adapt to this disorder in the cycle, which in the long run leads to gastrointestinal problems, communication with others or drug use, alcohol, decreased function at work etc. The results indicate that people are somewhat different from each other at the time of the peak of their physiological activity. Accordingly, people are divided into "morning" and "sunset" groups. The "morning" people usually sleep earlier and wake up sooner and their performance and abilities are higher in the morning than those who are "sunset", and the body temperature is 70 min earlier than "sunset" people [4].

Methodology

Literature search

Systematic searches were conducted in three databases from inception to 31st March 2020 to retrieve peer-reviewed articles, books, and PhD dissertations. Searches were conducted in Medline with EBSCOhost, in PsycINFO with Ovid, and in EMBASE with EMBASE.com. Additionally, reference lists of relevant articles were hand-searched, and references were included by the snowball method.

Results

Chronobiology and its effect on sport performance

It is confirmed that mass, strength and fiber type in muscle tissues are altered based on molecular mechanism of circadian rhythm. The specific circadian rhythm in the muscle tissue is related to fasting-feeding statues and is regulated by some genes. Myod1, ucp3, arogin1 and myh1 are involved in myogenesis by inducing satellite cells and myoblasts, lipid consumption, protein metabolism and myofilament rearrangement, respectively. All these genes are set up by BMAL1/CLOCK heterodimer. In addition to the presence of BMAL1/CLOCK system in muscle tissue, mechanical performance such as exercise can stimulate the expression of myod1 and myogenesis. Moreover, the absence of BMAL1 and CLOCK proteins lead to reduce strength and muscle mass and perturbation of myofilament scaffold. On the other hand, the lack of BMAL1 inhibits the expression of myod1, myfs, myogenin and genes related to WNT pathway and therefore myoblast differentiation is disturbed.

According to previous studies, similar to other tissues, lipid and carbohydrate metabolism are exerted as rhythmic and are affected by various factors such as molecular clock, nutritional statues, hormones and neural signals. Furthermore, it is reported that the presence of Bmal1 in muscular tissue impacts on the gene regulation for energy substrate consumption or storage that does not follow the rhythmic principle [31]. The gene involved in carbohydrate catabolism, carbohydrate storage and lipid synthesis is expressed in the beginning, middle and end of active site, respectively. In addition, lipolysis occurs in the middle of inactive period. All events control by endogenous molecular clock in muscular tissue are dependent on substrate quantity [31]. On the other hand, the insulin associated metabolisms including glucose uptake, transporter translocation to cell membrane, glycolysis, glucose oxidation, activation of key enzymes such as hexokinase and pyruvate dehydrogenase are affected by Bmal1 gene both in the gene level and enzyme activity [32, 33]. Another gene, rev-erbα is involved in lipid metabolism (both uptake and oxidation) through mitochondria biogenesis. In addition to rev-erbα, rorα has effects on lipid homeostasis and expression of specific transporter, carnitine palmitoyltransferase-1 in muscular tissue.

One of the most important issues in circadian rhythms is the existence of time changes in sports performance, physiological responses to exercise and sports performance [18]. As it has been proven, various sports performances are influenced by different times throughout the day and depend on intensities and the duration of the exercise [18]. Many studies have documented the fluctuations and changes in athletic performance at various hours of the day. For instance, it has been proven that central fatigue is higher in men in the morning and in women in the evening, and increased heart rate for women in the morning and for men in the evening. Bambaichi et al. [34] have reported significant changes in the isokinetic muscle strength of the knee-lowering muscles between different hours of the day and argued that muscle strength in the evening; is more than in the morning. The highest fat oxidation was observed for both obese and normal men in the evening more than in the morning [35]. Therefore, considering that excessive fat and overweight to carry out various missions and maneuvers in different fields can cause disruption and early fatigue in these forces, the best hours of fat burning and achieving weight loss and fitness is during the evening. Forsyth and Rayleigh reported day and night time changes in heart rate, oxygen consumption, and lactate threshold in female athletes. Jourkesh et al. [36] reported that the maximum anaerobic power of lactate was significantly different at different times of the day;

however, there were no significant changes in speed, agility, aerobic power and fatigue index between different hours of the day. In addition, changes in body temperature have been well documented and are considered as a major variable in changing circadian rhythms. The lowest changes in temperature during sleep have been reported at around 6 a.m. and from then on, waking up begins, the body temperature is increasing gradually and in the middle of the day there is a slight decrease and gradual increase and reaches the maximum at 6 o'clock [37]. The important thing is the presence of these body temperature fluctuations within 24 h and its relation to various sporting activities during this period has attracted the attention of many researchers. The body temperature was lower in the morning than in the evening and remained constant throughout the exercise [34]. Reilly and Garratt [18] reported that most of the world records and peak performance of athletes are usually gained in the evening, because during these hours, the internal temperature of the body is maximum and the worst performances would have been seen in the morning. Therefore, as the temperature rises from the moment of waking up to 6 o'clock and the physical performance of the troops is heavily influenced by the temperature variation of the body, the best time to increase efficiency and mobilize your troops for missions is in the afternoon hours. Reilly et al. [38] showed that in the early morning, the reaction times (both for audio and visual stimuli) is faster because the body temperature is at its maximum. Souissi et al. [39] also showed that the time to maximize and minimize sports performances, especially anaerobic exercise, can be estimated by recording the subterranean temperature.

Some researchers also looked at the relationship between body temperature changes and other variables related to exercise and sport performance, and presented different results, for example, flexibility as one of the physical fitness factors which demonstrates the ability of the muscle, joint and ligament to move in the greatest range of motion without damage and pain, may change a lot during the day.

Many researchers have shown that at 7 o'clock in the evening, than at 7 o'clock in the morning, the range of spinal motion in the neck region is much higher [18]. Baxter and Reilly [40] also investigated the effects of "different times of the day" on the factor of flexibility on 14 swimmers, and concluded that the best records would be at 13:30 and the lowest records at 6:30. All these changes are related to changes in body temperature. Gifford demonstrated the existence of day and night-time changes in flexion and lower back extension, shoulder joint rotation and bending to the front of the whole body [41]. Reilly and Garratt [18] also assessed the effect of different times of the day, experiences on the performance and some physiological factors of swimmers, and measured the flexural dimension of shoulder joint in both bending and internal rotation in two rounds of the day (6 a.m. and 6 p.m.) and measured the flexibility of the shoulder joint in two movements of bending and internal rotation in two rounds of the day (6 a.m. and 6 p.m.). The researchers concluded that although the shoulder joint flexion was more in 6 p.m. than at 6 a.m., the difference was significant only in the movement of the internal rotation [18]. Therefore, the best performance and efficiency in sport fields such as diving and swimming at 100 and 400 m breast stroke and the implementation of the mission of passing the river (with and without equipment) by the military, and also swimming at high distances, that involves flexion in the shoulder, neck and trunk areas which plays an important role will be done in the afternoon. It should be noted that according to the research, the main cause of increased physical flexibility in diving and swimming has been attributed to an increase in body temperature in the afternoon [18].

Hill and Smith [42] evaluated the effect of boarding rhythm on anaerobic power capacity. The researchers measured the anaerobic capacity of 9 male students at 4 different times of the day at 3, 9, 15 and 21 with Wingate test. The average of maximum anaerobic power at 21 o'clock was about 8% higher than at 3 a.m. The anaerobic capacity at different times of the day, at 15 and 21, was about 5% higher than the 3 and 9. These results indicate that the circadian rhythm is very effective in anaerobic power and capacity [42]. The capacity and anaerobic power in the afternoon is more in the morning, thus the execution of explosive and anaerobic movements by military forces should be done in the afternoon [43]. Another study was conducted by Hill et al. [43], which evaluated the high intensity performance of men and women affected by the time of the day. The subjects performed a very intense test of ergometer in the morning and afternoon randomly, and the load for all subjects was 5 W/kg for six women or 6 W/kg for eight men. The total work accomplished was 6.9% in the afternoon more than in the morning.

There was no effect between the times of the day on the distribution of aerobic and anaerobic power and gender [43]. Melhim et al. studied the effect of circadian rhythm on peak power and average power on 13 physical education students aged 18–21 years. Peak power and mean power of subjects were measured at 4 different times 3, 9, 15 and 21 with Wingate test and it was determined that circadian rhythm had a significant effect on peak power and mean power [26]. Another study was carried out to evaluate the effects of time on the comparative levels of 4 weeks aerobic training. The rhythmic effect of aerobic exercise program was studied on three groups of men who practiced at different times of the day. Each of the three groups were healthy athletes who acted on three occasions in the morning (9–9.30), in the afternoon (15–15.30) and at night (22–22.30), and each of the groups exercised for 30 min with 60% VO_{2max} on the ergometer bicycle. The athletes acted on a 4-week course

with 4 days a week. In different stages of exercise, heart rate, VO_{2max}, and lactic acid levels of subjects were measured [44]. The results showed that subjects undergoing training in the afternoon showed an increase in VO_{2max} and a significant decrease in blood lactic acid and heart rate. The results indicate that the aerobic capacity is often higher in the afternoon [38].

To improve the VO_{2max} and reduce blood lactic acid and reduce heart rate of military forces in maneuvers and tournaments fitness and endurance running that emphasize on endurance factor, it is better to move these activities to the evening hours. Reilly et al. [45] carried out a study on cardiovascular responses to exercise at different times of the day. The number of participants was 10 athletes who used a bicycle test to increase their test to 3, 9, 15 and 21 o'clock. The results of this study were as follows: The existence of a regular rhythm in the heartbeat of subjects during rest and recovery. There is a significant difference in heart rate during performance with 15 W output in different hours of the day, there was no significant difference between temperature and systolic and diastolic blood pressure [45]. Hill et al. [46] examined the effect of daytime body temperature on oxygen consumption in 27 subjects. Subjects used the ergometer in the morning and evening starting at 60 W and finishing at 160 W. They concluded that rhythm at body temperature may be due to the effect of rhythm in revealing metabolic responses to exercise, especially in VO_{2max} [46]. O'connor and Davis [47] examined the biological responses to exercise at different times of the day. Twenty-one women, at four sessions randomly participated in a series of submaximal exercises. Subjects participated in 20 min running, with 70% VO_{2max} at 8–16 and 12–20 o'clock. Their result showed that exercising and cardiovascular changes are affected by the time during which the exercise is carried out [47]. Murray et al. [48] also looked at whether patients with cardiovascular complications should practice in the morning or in the afternoon. It was concluded that the rate of cardiovascular events in cardiovascular rehabilitation exercises is 27.1 times higher than in the morning compare to afternoon [48] (Table 1).

According to acrophage, platelet aggregation, blood coagulation, spasticity of coronary arteries and occurrence of angina symptoms and sudden death in the morning have been proven. Therefore, it is recommended that military forces intending to participate in a tournament after a period of inactivity or detraining, until they have reached high levels of fitness, should avoid participating in professional competitions and performing missions that are essential for their high physical fitness. Baxter et al. [40] studied the effects of different times of day on swimming with maximum power. Subjects participated in breast stroke swimming with a distance of 100 and 400 m in five separate times between 6.30 to 22.00 o'clock. Implementation of tests revealed a significant linear difference at different times of the day and 3.5% progression for 100 m and 2.5% progression were observed for 400 m breast stroke swimming in the afternoon. In addition, the flexibility factor was the highest in the afternoon [40]. Marriott et al. [49] also examined the difference in heart rate between morning and afternoon exercise tests among patients with coronary artery disease. The subjects performed a special test on the ergometer at 3.00 a.m. and 4.30 p.m. Heart rate, systolic and diastolic pressure, perceived pressure, VO_{2max}, and lactate concentration during rest, maximal and sub-maximal exercise were evaluated. The results indicated that there was no significant difference between the mentioned variables in the morning and afternoon during the activity [49].

In order to find the optimum time to practice during the day in terms of safety and in relation to blood pressure, it examined nine healthy male students. The Bruce protocol was applied to them and blood samples were taken at rest and immediately after exercise for hematocrit and hormonal analyses. Heart rate and blood pressure were measured at rest every 3 min during exercise. The dual product (heart rate in systolic blood pressure) was calculated and practiced in three different time periods in consecutive hours in the morning, afternoon and evening and the following results were obtained:

1 The ratio of resting heart rate (which represents 1) during exercise early in the morning was significantly higher than exercise during the afternoon and evening but there was no significant difference in blood pressure.
2 The dual rest product (representing the number 1) had almost the same variation in all three training periods. However, during the intensive training early in the morning, it was significantly higher than other time ranges.
3 The accumulation of cortisol levels in the early morning was higher than other ranges, and increased after exercise early in the morning, but in other groups, this was not the case, and the results indicate that those with less practical storage capacity have a higher cardiac pressure to increase the load of training.

Considering that one of the indirect measurement methods for oxygen is myocardial dual product with lower index, the less pressure comes to the heart (dual product is lower in the afternoon). So the military will carry out missions and matches in which the heart is affected by ischemia at afternoon. Also, given that the macrophage secreted cortisol from 7 to 9 in the morning and its secretion is decrease in the afternoon, its high secretion in sports such as fitness, climbing, wrestling, judo, endurance duels, cycling, high-flying skates, martial arts and weightlifting, reduced the efficiency of the tournament and reduces the sport's record. So the time to run this tournament and participate in the operation

Table 1 Shows the results of research on factors such as sleep deprivation, bright light exposure (BLE), melatonin hormone, and trips, and its impact on physical performance of athletes and military force

Researchers	Population age/sex	Type of intervention duration and intensity of exercise	Rhythm type	Conclusion
Grandou et al. (2019) [7]	Military populations (review article)	Sleep loss	Aerobic capacity, anaerobic capacity, muscular strength and muscular endurance	It is difficult to establish the relationship between sleep loss and physical performance in military populations
Lucas et al. (2008) [75]	7 men and 5 women from three teams of four with a mean age of 36 years	Traverse venture partners	Maximal heart rate	64% HRmax in the first 12 h of the match 41% HRmax in the final 24 h of the match
Bambaychi et al. (2005) [34]	8 female national weightlifters amenorrhea, aged 24–36 years	One night deprivation	Testosterone and cortisol	No change in power or athletic capacity
Van Dongen et al. (2003) [76]	48 healthy subjects 21–38 years old	Sleep restriction to 4 and 6 h for 14 days	Awareness and work memory	Reduced alertness and work memory
Waterhouse et al. (2002) [77]	85 different people include athlete, support staff and university professor	Travel from west to east (UK to Australia) and pass through 10 time zones	Flight signs	Reducing flying symptoms on day flyers than night
Ohkuwa et al. (2001) [81]	10 men run long distances	Before performing the Wingate test, the subjects were placed to low light (50 lx) or high-light (5000 lx) for 90 min	Epinephrine, lactate, ammonia, blood and urine	Without changing lactate, ammonia, blood epinephrine No change in power
O'Brien et al. (2000) [78]	12 bike riders with an average age of 24.3 years	20 min of maximum cycling exposure 400–600 lx	Heart rate, oxygen uptake, alertness, muscle aches	No change in the indexes
Cain et al. (2007) [82]	8 Patients	40 days of life in isolation and compulsory incompatibility with your life (20 h) and 3 sessions of light exercise activities in low light	Melatonin Plasma Body Temperature	exercise activities have not played a role in the movement of circadian rhythm
Atkinson et al. (2005) [79]	12 active cyclists with 25–30 years	Take 5 mg melatonin and run a 2.5-min trial of Trill	Awareness, short-term memory, reaction time and athletic capacity	Reduced consciousness, short-term memory and reaction time No change in exercise capacity
Nindl et al. (2002) [80]	10 soldier men	High daily calorie intake (1600 kcal) and insomnia (2 h daily) for 72 h	Sleep Tolerance Capacity and Squat Jump Squat and Grenade Launcher	No change in sleeping capacity No change in breast power Decrease in the performance of squat jumps No change in shooting performance and throwing grenades
Young et al. (1998) [74]	8 Military Candidates Simulated by US Army Rangers	Sleep deprivation (4 h of daily sleep) and caloric imbalance (− 850 kcal) and real American ranger training for 61 days	Exercise Capacity	Maintain performance and exercise capacity

which is similar to these exercises should be moved to the afternoon.

Atan et al. [50] evaluated the endurance performance based on 24-h cycles on 38 male students aged 20–27 years and used Shuttle Run test to determine endurance performance. Measurement of endurance running was carried out at 9 a.m., 2 p.m. and 7 p.m. The results revealed that shuttle numbers and endurance performance were better at 2 o'clock in the morning than in the evening. Hammouda et al. [51] reviewed the performance of footballers following a yo yo intermittent recovery test in connection with biochemical responses. The central temperature and physical function were higher in the morning during the yo yo test than in the evening, and no effect was found between the index of perceived pressure and peak heart rate. Biochemical parameters had the highest values at 7 o'clock in the morning before and after the yo yo test. The results of a link between the daily fluctuations in metabolic response and the pattern associated with endurance performance showed that among the soccer players, most metabolic responses were observed in the evening, and endurance performance was even higher in the evening [51]. Hill [52] also concluded that the maximum oxygen consumption, the anaerobic capacity and kinetic of oxygen consumption, and athletic performance in the evening are higher than in the morning [52]. Souissi et al. (2012) showed that a 6-week training program would increase endurance and strength, especially after exercises in the evening hours. The progress in these two factors in the evening is more than the other hours. But according to this, many researchers have considered aerobic training hours to be appropriate in the evening [53]. Given that metabolic and biochemical responses in the evening are more than in the morning, and progress in endurance performance and aerobic indexes, the increasing power and kinetics of oxygen consumption in the evening has been proven [52].

Chronobiology and its effect on testosterone/cortisol and exercise performance

Steroid hormones such as testosterone (T) and cortisol (C) have a clear role in the circadian rhythm. The role of T is to preserve and synthesize protein in the body. On the other hand, C plays a catabolic role in the body and is released in response to stress. It has been proven that due to the anabolic and catabolic characteristics of these two hormones in the body, their effect on circadian rhythm and muscle is interrelated [14]. Because endogenous testosterone suppresses strength adjustments in healthy male participants, this hormone plays an important role in muscle compatibility. In normal conditions, testosterone/cortisol (*T*/*C*) board profiles peaked most early in the morning before its progressive decline throughout the day (Fig. 2). On the contrary, cortisol is a glucocorticoid, which is commonly used as a marker for both physiological and psychological stress. The prolonged and chronic increase of cortisol increases its inhibitory effects on the neuromuscular system. Cortisol's boarding profile is also similar to testosterone, its peak plasma is in the morning and it peaks again before sleep. There is a negative correlation between body function and long-term increase in salivary cortisol. Both steroid hormones and athletic performance play an important role in circadian rhythm. There are strong documentation for sports adaptations [54]. Circadian rhythms, hormonal profiles, play an important role in the production of favorable environments for anabolism. Therefore, optimum power and muscle adjustment are associated with resistance exercise. In addition, the proportion of *T*/*C* profiles with resistance exercise in the evening changes positively. Also, cortisol concentration is less before exercise in the evening. Therefore, increasing the *T*/*C* ratio by decreasing catabolic conditions is an advantage for training adaptations. Teo et al. [14] proved that the peak of physical performance and the peak of central body temperature are more in the evening. Therefore, the highest physical activity occurs in the evening as the body temperature rises [14]. Central body temperature has been used as the main indicator of circadian rhythm in biological processes and physical exercise; consequently, increasing body temperature leads to increased carbohydrate intake than fat as a fuel source. It also facilitates cross-links between actin and myosin in musculoskeletal units.

Chronobiology and its effect on time of exercise training

New evidence has proven that biomarkers of cellular and leukocyte damage in recurrent fast-paced exercise and a 30-s Wingate test in the evening are higher compared to the morning. Also, markers of antioxidant status such as TAS, UA, TBIL, total bilirubin and total antioxidant status were at the highest level before the repetitive speed test was

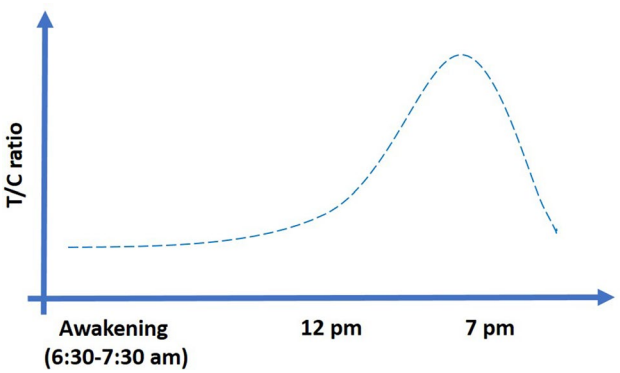

Fig. 2 Testosterone/cortisol (*T*/*C*) board profiles in different time of the day [54]

performed in the morning. Moreover, the levels of lactate were highest in the evening after the Wingate test was performed in the evening.

Lactate levels during fast-paced exercise are more in the evening than in the morning. This represents higher levels of muscle fatigue at this time of the day [55]. Differences in lactate response to exercise in the morning and evening are associated with increased catecholamines. This is because catecholamines respond with the same pattern to exercise. Broading central body temperature change influences lactate production during exercise. Elevated body temperature in the evening will increase the activity of the enzymes PFK (phosphofructokinase) and lactate dehydrogenase (LDH). The acrophase of these enzymes (biological markers of muscle damage) and immunological processes correlated with peak of oral temperature rhythm. An increase in these enzymes in the evening compared with morning in response to exercise is due to higher values of these enzymes, and higher primary strength during short-term maximum exercise in the evening [56]. Increased muscle fatigue in the evening during short-term maximum exercise was also due to higher levels of homocysteine (HCY) and biological markers of muscle damage; also, lower levels of antioxidant activity at these times of the day [57, 58]. Therefore, the short-term maximum functions at different times of the day will vary in range from 3 to 22%.

Melatonin is a hormone that plays an important role in the circadian rhythm of the temperature and the sleep and waking cycle. It is produced in the pineal gland of the brain and in the evening, it began to secrete and by light (its brightness) its effects are suppressed [59]. Different studies have reported that melatonin supplementation has neutral effects on body function, but its beneficial effects lead to a reduction of the consciousness, short-term memory and reaction time and prepare the body for sleep. Therefore, the use of exogenous melatonin can effectively adjust circadian rhythm with new sleep and wake cycle in athletes and shift workers. There is a very strong relationship between exposure to light and secretion of melatonin and alertness [59]. Bright light exposure (BLE) has been investigated as an effective tool for the circadian rhythm and the exact pattern of stage adaptation depends on the time the person is exposed to light, especially when BLE is used in the evening just before sleep and begins to release melatonin and reduce the temperature, it causes a delay of 2.39 h in the parameters (in other words, the onset of melatonin secretion and lowering of the temperature will be postponed). On the other hand, if the BLE is used in the normal wakefulness period, it will act as reversely pulls forward circadian rhythm in 1.49 h. In addition, 8 weeks of light physical activity in healthy people has increased morbidity and decreased unusual depression rates. However, those who were in bright light conditions (2500–4000 lx) had a stronger, more positive response than those who worked in normal light [60]. Shifting work creates a permanent inequality between endogenous rhythms and environmental symptoms and social constraints in the wake-up cycle and makes the person hardly adapt [60]. Signs of non-compliance with shift work are: reduce power and attention and reduce cognitive function, these complications become worse with the shift of continuity, but leaving a shift work plan somewhat reduces tolls and provides recycling.

A study conducted in the Netherlands military police unit suggests that job shifts are considered important predictors of family conflicts. The increase in these conflicts will peak at the peak of the weekend. Sleep deprivation has a significant effect on the performance of ultra-endurance sports. Research that evaluates the impact of sleep deprivation on military forces has concluded that if the deprivation of sleep is short-lived (72 h), its disorders are minimal, and if sleep deprivation is applied for long periods, the effects and disturbances are exacerbated. It is important to note that sleep deprivation and the reduction of energy calories in well-trained and ranger forces with a motive will not have much effect on their physical performance.

Discussion

One of the most contemplative issues in the field of circadian rhythms is the existence of time variations in exercise functions and physiological responses of the body to exercise [18]. As it has been proven, various sports performances are influenced by different times throughout the day and depend on intensities and the duration of the exercise [18, 61, 62]. Many studies have shown the oscillation and change of athletic performance over different hours of the day. Childs (2018) consider the effects of time of day and chronotype on cognitive and physical performance in healthy volunteers. They result provide evidence to support the notion that 'night owls' are compromised earlier in the day [63]. psychophysiological functions show maximum peaks at different times of the day, which could have either positive or negative effects on sports performance [15]. However, it is crucial to emphasize that is extremely difficult to control for all factors affecting physical performance and its circadian rhythmicity. Vitale and Weydahl [64] show that chronotype influences ratings of perceived exertion and fatigue scores in relation to submaximal and self-paced physical tasks performed in the morning: morning types (M-types) seem to have more of an advantage because they are less fatigued in the first part of the day than neither types (N-types) and evening types (E-types) [64].

Below are some tips for improving athlete's performance in different fields and the best time to participate in the tournament according to past research.

1 Pain tolerance and pain threshold of athletes in the afternoon and late afternoon are maximum and these athletes have higher performance (maximum pain threshold between 18 and 12 h and the minimum pain threshold between 0 and 3 a.m.) [26].
2 Given that the ability of individuals to perform sport activities depends on the time of the day (both in the morning and evening), the efficiency of morning person is higher in the morning than those who are evening and the degree of body heat of these people is 70 min earlier than evening people when they reach the peak. Coaches are advised that before engaging athletes in team and individual sport in tournaments, athletes with better performance in the morning or afternoon should be divided into two categories: morning and evening [4].
3 Men's central fatigue is higher in the morning and in women in the evening, but increased heart rate in men is higher in the evening and higher in women in the morning. It is recommended that competitions that lead to the central fatigue of athletes, especially for military athletes, should be held in the afternoon [37].
4 The isokinetic strength of the knee-lowering muscles in the evening is higher [65]. It is recommended that competitions that emphasize muscle strength, such as weight lifting and the strongest men, should be held in the evening.
5 The highest levels of fat oxidation have been reported in men in the evening [66]. It is recommended that soldiers who need fitness for various missions, and those who are obese and overweight will be disruptive to the mission; therefore, under the supervision of coaches, they should carry out a weight loss exercise program in the evening.
6 The highest body temperature and most global records and performance of athletes have been reported in the evening (6 o'clock) [18, 34]. The organizers of the tournament are advised to transfer recordings of elite and professional athletes to the evening hours.
7 The estimation of the maximum and minimum recording time of sports performances, especially the anaerobic exercise, has been proven by recording the sublingual temperature in athletes [67].
8 Flexibility factor varies in different hours of the day, for example, the best neck flexion at 7 o'clock in the evening and the best time in swimming trunks flexibility in the 13:30 h. Also, the best flexibility of the swimmer's shoulder is recorded in the movement of flexion and internal rotation during 6 o'clock in the evening. There was also a 3.5% improvement in 100 m swimming and 2.5% improvement in swimming of the 400 m breast stroke in the afternoon. It is important to note that changes in flexibility are consistent with body temperature changes [18, 41]. Overall, it can be said that in fields such as swimming and diving that require flexibility in the shoulder, neck and trunk areas, swimming competitions in the distance of 100 and 400 m' breast stroke are better implemented in the afternoon.
9 Acrophoresis secretes cortisol from 7 to 9 in the morning and lowers its secretion in the afternoon. As morning exercises are conducted in the armed forces in the morning, so also, most competitions such as wrestling, judo, climbing, taekwondo, fitness, endurance running and swimming at distances of 100 and 400 due to the number of athletes participating are implemented in the morning. It is strongly recommended that coaches and organizers of the tournament should improve the athletic performance and the acrophoresis secretion of cortisol hormone. Also, due to the destructive effects of this hormone on the performance of athletes, it is better to move the time of the tournament to the afternoon.
10 Urinary secretion of acrophoresis essential ions of the body such as sodium, potassium, calcium, magnesium, chlorine and bicarbonate occur in the middle of the day (noon) [68]. So it is recommended that, exercises such as cross country running, and running at 8000 m, 10,000 m, and running marathon and super marathon, which will lead to the loss of essential ions through sweating, be moved to the afternoon.
11 Oxygen consumed in submaximal exercise, maximum work tolerance, 95% VO_{2max} is more in the afternoon and the psychological perception of effort (in terms of heart rate) is higher in the morning. Therefore, it is recommended that the maximal and submaximal endurance tournaments be held in the afternoon hours.
12 It is recommended that physical activity that requires movement accuracy, learning, memory, alertness, concentration, and recall of psycho-motor skills, such as shooting and chess, and other competitions that require careful attention be implemented in the morning [69, 70].
13 Sudden deaths acrophases due to cardiovascular problems, platelet aggregation, coagulation, coronary artery spasms, and angina pectoris symptoms usually occur in the morning [48, 71, 72]. Athletes who intend to participate in the tournament after a period of separation from the sport should be recommended as long as they are ready for physical fitness, but they should not attend the tournament if not fit because sudden death occurs in people with poor physical fitness and increases in severe physical activity.
14 The maximum aerobic power measured at 21 o'clock is about 8% higher than 3 a.m. [43]. It is concluded that the anaerobic capacity and aerobic capacity in the afternoon are more than in the morning. So it's better to have matches that focus on aerobic and aerobic power factors in the afternoon.

15 VO_{2max} measured in athletes who practice at afternoon is higher and there is a significant decrease in blood lactate and heart rate [38]. It is recommended that competitions such as physical fitness and endurance running with different distances that emphasize the aerobic factor should be held in the afternoon.

16 In a study done on persons aged 60 years and above, the effect of circadian rhythm on knee stiffness, short-term memory, flexibility, muscle strength and mood was evaluated and the following results were obtained:

   a The highest knee stiffness was at 5–6 a.m. and 6–7 p.m., short-term memory was 8–10 in the morning, and the flexibility peak was observed at 11–13 p.m., most power was obtained at 11–15 o'clock, and the mood was at best possible at 17:19 o'clock. It is recommended that the tournament is organized for people aged 60 years and above and based on the information obtained.

17 Given that the pattern of inappropriate work shift of military forces leads to increasing family conflicts of job dissatisfaction and reducing their morale and their ability, shifts are suggested to be rotational and select a forward sequence (shift in the morning, afternoon, night) and even coordinate with their work plan [73]. Also, sleep deprivation and a reduction in time-consuming energy for troops are the most disturbing, which is faced with reduced motivation. In other words, the quality and quantity of sleep below the optimal daily rate, especially those who carry out heavy military operations for a long time, along with family offenses and family responsibilities, will lead to sleep deprivation and aggravation of sleep deprivation disorders [74].

Conclusion

Military forces show the power of combat in every country and as their physical fitness and physical performance improves; they perform well in their mission. Overall, the results of the research indicate that the circadian rhythm on the performance of the sport and factors such as aerobic and anaerobic power, muscle flexibility, cardiovascular endurance, alertness, accuracy and focus, reaction time, records, fatigue index and pain perception, body temperature, arousal and mood, memory, sleep and awakening, hormonal secretion, renal function and fluid regulation, electrolyte balance, systolic and diastolic blood pressure, heart rate, fat oxidation, coagulation events, coronary artery bypass graft and sudden death is great. The organizers of the tournament and coaches should consider the effects of circadian rhythm on the athletic performance of the military, schedule competitions and sports exercises.

According to trained and skilled military forces, to carry out missions and participate in maneuvers, competitions as well as sports events that require high physical fitness, the personnel involved should be fit in order to carry out water, earth, and in any circumstances missions. Before hiring an armed force, they should be evaluated for circadian rhythms and chronobiology.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

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