ANKARA UNIVERSITY SPORTS SCIENCES FACULTY

PERFORMANCE ANALYSIS IN SPORTS APPLICATION & RESEARCH CENTER

PERFORMANCE ANALYSIS IN SPORTS AND EXERCISE

Volume: 1

Issue: 1

December 2022

PERFORMANCE ANALYSIS IN SPORTS AND EXERCISE (PASE)

Preface

The Performance in Sport and Exercise aims to provide its readers with the highest quality and effective articles through a careful peer review and editorial work process. The articles to be published include both detailed scientific methods and guided results for sports professionals, providing the opportunity for immediate application in the field. In this sense, it will contribute to the field of sports sciences by fulfilling the requirements and observing ethical principles.

The Performance in Sport and Exercise is the official journal of Ankara University Performance Analysis in Sports Application and Research Center (ASPAM). The ASPAM is a center established to combine theoretical knowledge and experience in all sports-related subjects and to contribute to the field of sports sciences.

The Performance in Sport and Exercise is published biannually (June and December) in English. The Journal publishes scientific papers in the scope of sport, exercise, physical activity, exercise and health, sports medicine, biomechanics, sport and exercise physiology, sport and exercise psychology, performance in sport, training, and technology in sport. As the editorial board, we sincerely wish the first issue of our journal to be beneficial to the sports science community.

Table of Contents

Effects of Caffeine on Physical and Cognitive Performance: A Review

Raci KARAYİĞİT, Muhammed Uygar SERTKAYA 1-20

Investigation of Relationships Between Tennis Serve Performance, Anthropometry, Somatotype and Range of Motion According to Sex

Mustafa Can ESER 21-30

Comparison of the Home-Court Performances of Successful and Unsuccessful Teams at Euroleague Before and After Covıd-19 Pandemic

Tugay DURMUŞ, Mehmet GÜLÜ 31-40

Does the Tibialis Flexion Exercise Affects Sprint Performance in Youth Soccer Players?

Aysberg Şamil ÖNLÜ, Mete Berk DEMİRYOL, Erdem ÇAKAN 41-52

The Changes on HRV after a Wingate Anaerobic Test in Physically Active Adults

Veli GÜL 53-59

Performance Analysis in Sport and Exercise

Ankara University Performance Analysis in Sports Application and Research Center

Available online 5 December 2022

Effects of Caffeine on Physical and Cognitive Performance: A Review

Raci Karayiğit [1*], Muhammed Uygar Sertkaya [1]
[1] Faculty of Sport Sciences, Ankara University, Ankara, Turkey

Abstract

Caffeine is one of the most consumed nutritional ergogenic supplements by athletes. In the literature, it is now widely accepted that caffeine taken 60 minutes before exercise improves performance. There are different methods of caffeine intake; caffeinated gum, coffee, anhydrous, and gel forms are among the most commonly used. Generally, the ergogenic effect sizes of different forms of caffeine consumption do not differ significantly. The effectiveness of caffeine doses of 3-6 mg/kg has been proven. However, in recent years, doses <3 mg/kg have also begun to be investigated, and some studies have reported positive effects. In addition, it can be stated from the literature that there is no difference in the responses of male and female athletes to caffeine. It can be argued that the distribution of the CYP1A2 gene allele (AA, AC), which is responsible for the metabolism of caffeine, may change the physical and cognitive responses to caffeine and that athletes should consider this factor

Key Words: Coffee, athletic, ergogenic, supplement

INTRODUCTION

Nutrition has been one of the main factors in the development of physical and cognitive performance, which is of great importance for the continuation of the generation throughout the evolutionary process, especially in the human species (55). The relationship of nutrition with physical-cognitive health and/or performance is of vital importance, especially for elite athletes. Although the cardiovascular and respiratory systems are thought to be the most important factors limiting exercise performance, saturation of nutrient stores and the athlete's nutritional diet are also among the main limiting factors (44). When viewed from a wider perspective, it can be said that 3 factors determine the upper limit of an elite athlete's performance: genetics, training and nutrition. Following the intake of macro and micro nutrients according to the training and competition period, the athlete can increase their physical and cognitive performance by planning their nutritional ergogenic aid intake.

Nutritional ergogenic (energy-generating) supplements are widely used by athletes and sedentary individuals for many different purposes (7).

Caffeine

Caffeine, creatine, beta alanine, bicarbonate, nitrate and carnitine are reported to be the main supplements that most affect performance and have proven benefits in the current literature (11). Dose, timing, consumption frequency, gender and genetics are the most important factors affecting the ergogenic effect size of the athlete's supplement consumption. Supplement consumed without paying attention to these parameters can cause more harm than good. Among them, caffeine is by far the most consumed supplement by athletes, and hundreds of scientific studies each year reveal its effects on performance (2). Caffeine, whose chemical name is 1,3,7-trimethylzantine, takes its name from its C8H10N4O2 formula and molecular structure. Today, 80% of the 2öşe2's population consumes an average of 200 miligrams (mg) or 3 cups of espresso per day, making caffeine the most consumed drink after water (61). Among these plants, coffee, tea, cocoa, yerba mate and cola plants contain the most caffeine. Caffeine consumed in the late hours makes us sleepless and increases the feeling of vitality, which is associated with binding to adenosine receptors and eliminating the purported effects of adenosine (2). Caffeine appears in the blood immediately after ingestion and peaks in approximately 45-90 minutes. Genetic differences are the most important factor affecting the metabolic rate of caffeine. 3 mg of caffeine per kilogram (kg) can increase blood levels to 15-20 micromoles per liter, 6 mg/kg caffeine to 40-50 micromoles and 9 mg/kg caffeine to 60-75 micromoles (52). Factors such as whether caffeine is taken at once or at intervals, gender, amount of muscle mass, frequency of habitual consumption are metabolic rate determinants and are among the factors that should be planned in use. In addition, the form in which caffeine is taken determines the rate of absorption. Different forms of caffeine are digested at different rates, although the total amount and velocity of digestion are the same (46). Caffeine, which is metabolized by the cytochrome P-450 liver enzyme and broken down into parasanthine (85%), theobramine (10%) and theophylline (5%), completes its half-life between 3.5 and 5 hours. It takes approximately 24 hours for caffeine to be completely eliminated from the whole body. However, it is known that the ergogenic effect does not last for 24 hours (9). Athletes who did not regularly consume caffeine significantly increased their aerobic endurance compared to placebo even 1, 3 and 5 hours after 5 mg/kg caffeine intake. Athletes whos regularly consume caffeine developed tolerance and their aerobic endurance increasd significantly after only 1 and 3 hours (9).

For the last 10 years, it has been thought that caffeine improves aerobic endurance, sprint-style activities and cognitive performance (executive functions, reaction time, attention) by adenosine receptor antagonism, and muscular performance types (strength, power, endurance) by increasing sodium/potassium pump activation (2, 60, 66). Since caffeine is molecularly similar to adenosine, it binds to adenosine receptors in the brain tissue, reducing the feeling of fatigue-increasing negative effects of adenosine on the nervous system. For example, caffeine blocks the A_{2a} receptor in the striatum, activating the D2 receptor of dopamine and increasing the triggering effect of dopamine on psychomotor activities (1, 30). Also, caffeine may act directly on muscle tissue. Carins et al. (1997) found that high doses of caffeine increase power production when potassium is inhibited. Another mechanism by which caffeine is effective may be that the increase in blood glucose level increases the sodium/potassium pump (60). It has been previously shown that elevated plasma glucose inhibits the deterioration of the electrical properties of the muscle fiber membrane (53). Increasing the activation of the sodium/potassium pump with caffeine intake may provide an increase in performance especially in high-intensity interval exercises and muscular endurance exercises consisting of repetitive contractions.

Topics to Consider in Caffeine Consumption

After decades of scientific research, it is now almost conclusively proven that caffeine improves athletic and cognitive performance (54). However, as in the use of all other nutritional ergogenic supplements, there are main issues to be considered by athletes in the consumption of caffeine. Athlete or trainer, in order not to cause more harm than good: it is of great importance to plan caffeine consumption by considering factors such as 3öşe, timing, gender, consumption frequency, side effect, training status, placebo effect, annual consumption periodization, genotype and chronotype (6). For now, although not for amateur athletes, anti-doping rules for athletes competing at national and international level are constantly updated by the World Anti-Doping Agency (WADA), and athletes are kept under strict monitoring. While aiming to increase sportive performance with the use of caffeine or another supplement, it is necessary to avoid use that can be considered as doping. Caffeine was first included in the list of banned substances by the International Olympic Committee in 1984 and by WADA in 2000. Exceeding a dose of 15 micrograms/milliliter in the urine was counted as doping. In 1985, this rate was reduced to 12 micrograms/milliliter (87). These limits were set to distinguish between the sociocultural use of caffeine and its use for sports performance enhancement. However, later scientific research has shown that caffeine can increase athletic and cognitive performance at much lower doses (77). That's why WADA has removed caffeine from its list of banned substances and added it to its list of monitored substances. Ironically, the amount of caffeine in urine samples taken from athletes in international competitions before 2004 was much higher than after 2004 (87).

Believing that one has made a positive attempt, without actually taking the active substance, the placebo effect, which has beneficial results, shows its effect in the ergogenic use of caffeine as in medical sciences. Anderson et al. (2020) revealed that the wingate anaerobic test performance of athletes can be increased with the placebo effect. Although there is not much research on whether the training status of athletes affects the ergogenic effect size of caffeine, Apostolidis et al. (2020) classified the neuromuscular and cardiorespiratory performances of twenty football players as high and moderate and examined the effect of 6 mg/kg caffeine on exhaustion time and vertical jump performances. In conclusion, athletes with high or moderate neuromuscular and cardiorespiratory endurance all significantly improved their performance with 6 mg/kg caffeine intake. As with any supplement, caffeine intake also has some side effects that vary individually. The most common side effects are; heart palpitations, nausea, headache, insomnia and anxiety (14). Caffeine taken especially before evening workouts can negatively affect the time to sleep and sleep quality (27). In addition, the increase in the frequency of caffeine consumption also increases the level of chronic anxiety, and this may cause instantaneous performance drops and defeat in some branches. Side effects, which are directly proportional to dose intake, can be reduced by using lower doses (64). Before the competition, the athletes can try different doses on themselves and observe the side effects. For many years, athletes and coaches have been aware that training should be periodized annually, monthly or weekly. In recent years, due to the fact that nutrition also affects training adaptation, it should be periodized according to the annual training period (44). In an article published in 2021, Pickering and Grgic (2021) reported that caffeine intake should also be planned according to training and feeding periods. Considering the importance of the competition for the athlete, the tolerance effect of caffeine can be reduced by avoiding or reducing caffeine intake in technical-tactical training sessions, and annual periodization can be planned according to the genotype of the athlete (67).

Dose

In the literature, caffeine taken under a dose of 3 mg/kg is classified as a low dose, a medium dose between 3 and 6 mg/kg, and a high dose if >6 mg/kg (40). After hundreds of studies, it has been shown that caffeine taken in low doses also improves performance (77). Caffeine taken in doses of 3-6 mg/kg provides a performance increase between 1% and 8% in aerobic exercises, team sports and exercises with high glycolytic activity demand (56). Pallares et al. (2013) reported that caffeine intake at doses of 3, 6 and 9 mg/kg significantly increased muscular strength, but a dose of 3 mg/kg could increase strength at low weights, and 9 mg/kg dose was effective for strength gain at higher weights. He also reported that although 9 mg/kg caffeine significantly improved power performance, it had some side effects that lasted for 24 hours. Spriet (2014) suggested that the performance-enhancing mechanism of low doses of caffeine is central rather than peripheral. Zhang et al. (2020) investigated the effects of low (3 mg/kg), medium (6 mg/kg) and high (9 mg/kg) doses of caffeine on cognitive performance and brain activations and found that 3 mg/kg dose was more effective in activating cognitive functions than 6 and 9 mg/kg doses. With the research done by Zhang et al. (2020), Spriet's (2014) hypothesis was confirmed and it was revealed that low doses of caffeine can stimulate the central nervous system. Doses higher than 3 mg/kg may be required to activate the peripheral mechanisms of caffeine. The dose of caffeine that should be consumed for acute performance improvement is related to the dose of caffeine consumed regularly (+2-3 months) (68). It has been reported that for an acute performance increase, the athlete should take slightly more caffeine than the dose of caffeine taken in training and competitions throughout the year. However, increasing the dose of caffeine determines the size of the side effects according to the individual athlete and sports branch. Some studies have suggested that increasing the dose of caffeine creates changes in oxidized substrates and increases fat burning, thus increasing the performance of long-term aerobic exercise by providing backup of muscle glycogen stores (22, 79). Studies on dose-response in the literature are generally between 3 and 6 mg/kg doses. More research is needed examining doses less than 3 mg/kg. In addition, performance responses to caffeine at the same doses may differ between genders (59). There is a need to examine the effects of very-low (≤ 3 mg/kg) caffeine intake on different performance parameters by directly comparing female and male athletes and measuring side effects. Also, no studies to date have investigated the effects of low, moderate, and high-dose caffeine intake on cognitive performance in male and female athletes. To make more suggestion, further research is needed in these topics.

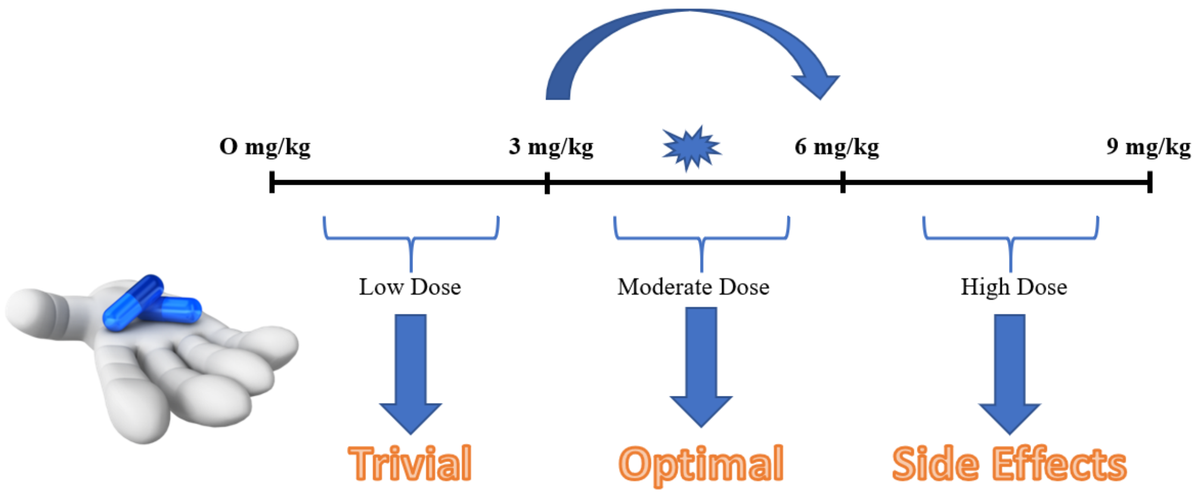

Figure 1. Dose response of caffeine

Gender

One of the main determinants of athletic performance is gender. Hormonal differences lead to gender differences in body composition, aerobic capacity and anaerobic threshold values (81). Therefore, gender-specific training and nutrition plans should be made. Although the effects of caffeine on sportive and cognitive performance are known, there is not much research directly comparing genders (36). Kaçoğlu (2019) reported that low-dose caffeine intake did not significantly increase 30-second wingate performance in adolescent female handball players, and that dose-response studies should be conducted in placebo-controlled in future studies. Skinner et al. (2019) investigated the effects of 3 mg/kg caffeine intake on time trial performance by directly comparing 16 male and 11 female elite cyclists and reported that 3 mg/kg caffeine significantly improved performance, but there was no difference between genders. Sabblah et al. (2015) examined the effects of 5 mg/kg caffeine intake on 1-repetition maximum (1RM) muscle strength and muscular endurance performances, and 10 male and 8 female athletes participated in the study. As a result, both male and female athletes significantly improved their 1RM performance in the caffeine trial, but muscular endurance performance increased only in males. The authors reported that the effects of different doses of caffeine intake on muscular performance should be compared between genders. In the literature review, no research to date has examined the effects of caffeine intake on cognitive performance by directly comparing genders. Since only 13% of the studies in the literature were conducted on women, recommendations regarding the use of caffeine cannot be considered accurate for female athletes directly (73). Also, the effects of low doses of caffeine have never been studied before in female athletes.

Whether there is an ergogenic difference between the sexes of caffeinated coffee Clarke et al. (2019) and it was revealed that 3 mg/kg dose of caffeinated coffee significantly increased 5 km cycling time-trial in men and women. Most of the studies on caffeinated coffee in the literature are on aerobic endurance and men (2). Also, the effects of caffeinated coffee on the sprint performance of female athletes have never been investigated until now. However, for the first time, Karayiğit et al. (2021), investigated the effects of different doses of caffeinated coffee intake (3-6 mg/kg) on muscular endurance, cognitive performance and heart rate variability in female athletes. In conclusion, Karayiğit et al. (2021) found to improvement in muscular endurance and cognitive performance with both 3 and 6 mg/kg of caffeinated coffee intake. Further, these performance enhancements did not lead to a cardiovascular load which shown by heart rate variability parameters.

Time

The pre-exercise caffeine consumption timing is generally recommended as 60 minutes. Plasma level peaks at 60 minutes following caffeine intake (38). During 2-3 hours of high-intensity exercise, caffeine shows its effects more when fatigue begins to occur. In this regard, caffeine intake does not always need to be taken before exercise. Caffeine taken during exercise, just before the onset of fatigue, has been shown to increase time-trial performance more, especially as the exercise duration gets longer (74). According to the results of this research, it can be thought that caffeine may be more effective in marathon and cycling-style sports, in case of fatigue. The time of intake of caffeine is directly related to the form of caffeine consumed. For example, caffeine taken with gum or cola is digested faster than the anhydrous form taken in capsules, and therefore the intake time of caffeine taken with gum or cola should be 5-10 minutes before exercise (40). In a study conducted with caffeinated gum, it was shown that caffeinated gum improves performance just before exercise, but chewing it 1 or 2 hours before has no significant effect (71). Because caffeinated gum comes into direct contact with enzymes in the oral cavity, it may be digested faster and enter the bloodstream faster. This makes caffeinated gum attractive to some athletes. The same is not true for caffeinated coffee. Caffeinated coffee intake is the same as the timing of anhydrous caffeine intake. Trexler et al. (2015) reported that 3-5 mg/kg of caffeinated coffee or anhydrous caffeine taken 30 minutes ago did not increase lower-upper body 1RM strength and 80% 1RM strength muscular endurance performance. Kara et al. (2019) revealed that caffeine supplementation taken 60 and 120 minutes ago did not significantly affect performance in short-term high-intensity activities in amateur football players. Athletes can plan their own intake timing by trying the caffeine timing before in training.

Form

Athletes generally prefer anhydrous or coffee form for physical and cognitive performance increase (40). Caffeinated gum, aerosol, energy bars, gels and nasal sprays are some of them. Caffeinated chewing gum can be preferred by athletes during early morning training or competitions, as it is digested faster. When we think nationally, there is no sale of caffeinated gum and other forms in our country. Athletes in our country have to realize their caffeine intake with the consumption of caffeinated coffee. It is known that long-term coffee consumption significantly reduces the risk of chronic diseases (21). Along with the thousands of polyphenols and catechins it contains, coffee is consumed by people as a health and physical-cognitive performance enhancer and is socioculturally accepted. It has been shown that increasing the amount of caffeine consumed with coffee daily up to 400 mg does not have a negative effect on health (25). Denoeud et al. (2014) stated that the daily consumption of coffee in the world is 2.2 billion cups. In addition to containing caffeine, coffee also contains substances that have the potential to change the effects of caffeine in coffee, such as chlorogenic acid, ferulic acid, and caffeic acid (41). Whether these substances reduce the effects of caffeine has been examined by many studies. Richardson and Clarke (2016) examined the effects of 5 mg/kg anhydrous caffeine and caffeinated coffee intake on squat endurance performance of male athletes at 60% 1TM intensity and reported that both anhidrosis and coffee form significantly increased muscular endurance performance. But in another study, Clarke et al. (2016) revealed that lower doses (3 mg/kg) of caffeinated coffee and anhydrous caffeine did not significantly increase sprint performance. The authors suggested that the fact that the participant group consisted of untrained individuals could explain the ineffectiveness of caffeine. Much more recently, there have been many studies suggesting that caffeinated coffee significantly improves physical performance (18, 66).

Caffeine Consumption Frequency

It is known that caffeine’s “adenosine receptor antagonism” is the main mechanism in increasing sportive and cognitive performance (1, 88). However, physiologically, the organism develops an adaptation to long-term caffeine consumption, as it responds to any chronic condition. Although it has not been clarified exactly from which adenosine subreceptor (A_1, A_{2A}) sportive and cognitive performance arises, it has been reported that chronic caffeine consumption increases adenosine A_1 and A_{2A} receptor concentrations in the striatum and brain regions responsible for the coordination of voluntary movements (80, 29). Therefore, chronically consumed caffeine by athletes may lead to tolerance and affect performance responses resulting from acute caffeine intake. In the literature, there are conflicting studies on this subject. Irwin et al. (2011) reported that consumption of 3 mg/kg caffeine for 4 days followed by withdrawal had no significant effect on time-trial performance. In another study, male athletes who consumed 3 mg/kg caffeine for 4 weeks developed tolerance at the end of 4 weeks and could not acutely respond to caffeine in time-trial performance (8). The authors suggested that there was no significant difference in serum cortisol and prolactin hormones measured as central noradrenergic and dopaminergic indicators, and that tolerance may have arisen from another central nervous pathway. Similarly, in athletes who do not consume caffeine regularly, 3 mg/kg of caffeine intake per day was reported that sprint (49) and submaximal aerobic (70) exercise performance increased until the 18^{th} day, but significant decreases in the size of the response to caffeine occurred after the 18^{th} day. On the contrary, there are studies that describe the development of tolerance to caffeine responses as a myth and reveal that regular caffeine consumption has no effect on performance responses from acute caffeine intake (35, 23).

This difference between studies may be due to the training status of the participants, test differences, and most importantly, the different grouping of caffeine consumption frequency. Filip et al. (2020) stated that the regular caffeine consumption grouping differs a lot in the literature, and in future studies, those with <25-75 mg/day caffeine consumption are "low", those with 200-450 mg/day "moderate", and those with +450 mg/day stated that grouping them as "high" will ensure standardization and achieve more reliable results. In addition, Pickering and Kiely (2019) suggested that acutely ingesting more than the caffeine dose they regularly consume may eliminate the effect of tolerance. For this, athletes with different consumption frequencies need to be affected by different doses. Most of the tolerance studies in the literature are on aerobic endurance performance and men. In addition, the relationship between acute caffeinated coffee intake and tolerance has never been studied to date.

Genotype

Genetic differences determine how nutrients are metabolized, absorbed, and used. The gene-diet interaction, which has important effects on health and performance by affecting metabolic pathways, has now begun to be investigated a lot in the sports science literature (83). Caffeine is one of the most researched substances in the field of nutrigenomics. The individual differences in the effects of caffeine intake on sportive and cognitive performance led researchers to investigate genetic factors. The CYP1A2 and ADORA2A genes, which are responsible for the metabolism, sensitivity and response of caffeine, are among the most studied. Yücesoy (2017) examined the allele distribution of CYP1A2 genetic polymorphism in short and longdistance runners in his master thesis and reported that the gene allele that metabolizes caffeine more slowly is seen more. The study with the largest participant group to date, Guest et al. (2018), while all participants increased their endurance performance by 3% with 4 mg/kg caffeine intake, only participants with AA genotype (fast metabolism) responded significantly to 2 mg/kg caffeine intake. Similarly, in another study, participants with the AA genotype responded to caffeine, while those with CC genotypes did not (86). On the contrary, there are studies reporting that there is no difference in caffeine response between genotypes (3), and even only slow metabolisers with CC genotypes respond to caffeine (65). Although the effects of genetic factors on caffeine responses are not known for now, athletes can still plan individual caffeine intake by determining their CYP1A2 genotypes.

Caffeine Effects on Physical and Cognitive Performance

In Olympic competitions, even a 1-2% performance increase can lead to winning or losing a gold medal (15). Since elite athletes at the Olympic level are physiologically at the highest level of genetic potential, they have to create their training, recovery and nutrition plans by making use of all scientific methods. Nutritional supplements, such as caffeine, whose use is not prohibited and whose significant effects on performance have been proven, are almost “pebble on the beach” for athletes. The significant effects of 3-6 mg/kg caffeine intake on aerobic endurance have been demonstrated by dozens of studies in both male and female athletes (76). In the last 10 years, the effects of caffeine on muscular strength and muscular endurance performance have been studied more (84). As in aerobic endurance, many studies showing that caffeine intake at doses of 3-6 mg/kg significantly increases muscular endurance, in particular, have been included in systematic reviews and meta-analyses (31). However, it has been reported that the effects of 1TM on muscular strength performance should be investigated further (36). Men metabolize caffeine faster than women due to greater CYP1A2 activation (62), so performance responses may also differ. However, Skinner et al. (2019) and Clarke et al. (2019) reported that 3 mg/kg of caffeine intake increased aerobic endurance performance in men and women at the same rate. During strength and muscular endurance training, neural recovery is of great importance in order to maintain muscle performance after repetitive contractions. Although the gender differences in neural responses to resistance exercises are not well known, it is known that women are more resistant to fatigue and recover more quickly in low-intensity and slow-paced resistance exercises than men (42). Recently, it has been found that, despite the same level of neuromuscular fatigue in response to resistance training, there are different sex-specific cortico-motor regulation mechanisms in the corticospinal pathways (16). Since caffeine intake also increases performance by stimulating the central nervous system, its effects on strength and muscular endurance performance may differ between genders. While 5 mg/kg caffeine intake significantly increased the chest press 1RM strength performance in male and female athletes, it increased muscular endurance performance only in men (72). The authors reported that a similar protocol should be applied to subgroup muscles with larger muscle group size in future studies. Lara et al. (2021), on the other hand, performed the effect of caffeine intake on sprint performance for the first time by comparing the genders and reported that the 3 mg/kg dose significantly increased the 15 second adapted Wingate peak and mean power for both genders. Since the research group consisted of only those with “low” caffeine consumption frequency, it was reported that the answers of those with “medium” or “high” consumption frequency should be examined with the same protocol. Considering that after 20 days of caffeine intake, tolerance developed in the 15-second wingate performance responses to 3 mg/kg of anhydrous caffeine intake (49).

In the literature, the possible effects of caffeine consumption frequency on performance responses are mostly on aerobic endurance, and its effects on muscular performance have only been investigated a few times. Grgic and Mikuliç (2020) revealed that 3 mg/kg caffeine intake significantly increased 85% 1RM chest press endurance and wingate performance in male athletes with both low and high caffeine consumption frequency. In addition, it was reported that 3 and 6 mg/kg caffeine intake significantly increased chest press 1RM strength but had little effect on 50% 1RM muscular endurance performance in female athletes with high caffeine consumption (33). Similar findings revealed that 3, 6 and 9 mg/kg caffeine intakes did not increase chest press performance in male athletes with high consumption frequency (85). On the contrary, in a study on female athletes with low caffeine consumption frequency, 3 and 6 mg/kg caffeinated coffee significantly increased squat endurance performance but did not affect chest press performance (48). There is a need for research that directly compares the genders and examines the effects of caffeine intake at lower doses (<3 mg/kg) on lower and upper body strength and muscular endurance performance. In addition to exercise performance, the effects of caffeine intake on sports branch-specific performances, where cognitive performance is important, have recently been studied. In a systematic review, it was reported that caffeine doses up to 300 mg significantly increased different cognitive performance parameters (attention, alertness, reaction time) (57). In addition, studies in the literature report that caffeine intake increases both physical and cognitive performance more after sleep deprivation (51, 57). Contrary to physical performance, it has been reported that lower doses are more effective for cognitive performance increase, rather than high doses in one go (51). In this regard, the effects of low-dose caffeine intake on the cognitive performance of athletes should be compared with higher doses. The results of other studies measuring branch-specific cognitive performance differ. Foskett et al. (2009) reported that 6 mg/kg caffeine intake significantly increased cognitive performance parameters measured by ball control and accuracy in football players. Similar findings, also confirmed by Stuart et al. (2005). However, there are studies stating the opposite (13, 69). It is thought that the different results can be explained by the difference in the test protocols used (flanker, simon or stroop task), the participants and the amount of caffeine dose. In recent studies, studies have been published reporting that generally 3 and 6 mg/kg caffeine intakes increase the reaction time and accuracy rates and increase cognitive performance significantly. Duncan et al. (2019) reported that cognitive performance increased significantly in addition to increasing upper body wingate performance. The results of this research are important for sports branches such as wrestling, where both upper body performance and cognitive processes are important. Almost all of the above-mentioned studies are on men. Bottoms et al. (2013), in his study on 4 female and 7 male fencers, reported that 3 mg/kg caffeine intake had a significant effect on fencing skills, but did not increase cognitive performance. As far as is known, there is no other study examining the effects of caffeine intake on cognitive performance by comparing the genders and frequency of consumption of different doses of caffeine. Table 1 and 2 summarized the studies in these topics.

Table 1. Effects of caffeine on cognitive performance

Reference	Participant	Dose	Time	Form	Test	Result
Bottoms et al., 2013	4 female 7 male	3 mg/kg	90 min.	Anhydrous	Stroop Task	No effect
Duncan et al., 2019	12 males	5 mg/kg	60 min.	Anhydrous	Flanker Task	Beneficial
Foskett et al., 2009	12 males	6 mg/kg	60 min.	Anhydrous	Test Batery	Beneficial
Karayigit et al., 2021	17 females	3, 6 mg/kg	60 min.	Coffee	Flanker Task	Beneficial
Zhang et al., 2020	10 male	3, 6, 9 mg/kg	60 min.	Anhydrous	Stroop Task	Beneficial with 3 mg/kg

Table 2. Effects of caffeine on physical performance

Reference	Participant	Dose	Time	Form	Test	Result
Anderson et al., 2020	10 trained cyclists 9: male-1: female	280 mg	45 min.	Coffee	30 seconds Wingate	No effect
Apostolidis et al., 2020	20 male soccer player	6 mg/kg	75 min.	Anhydrous	Time to exhaustion	Beneficial
Clarke et al., 2016	12 recreationally active males	3 mg/kg	45 min.	Coffee and Anhydrous	Repeated sprint cycling	No effect
Clarke et al., 2018	13 trained male runners	3 mg/kg	60 min.	Coffee	1 mile race	Beneficial
Clarke et al., 2019	19 male – 19 female	3 mg/kg	60 min.	Coffee	5 km cycling time trial	Beneficial
Filip-Stachnik et al., 2021	21 resistance trained female	3 mg/kg 6 mg/kg	60 min.	Anhydrous	1-RM strength	Beneficial
Grgic et al., 2020	24 resistance trained male	3 mg/kg	60 min.	Anhydrous	Wingate Resistance Exercise	Beneficial
Kaçoğlu et al., 2019	18 female henbtol player	0,05 g/kg	60 min.	Coffee	30 seconds Wingate	No effect
Kara et al., 2019	12 male soccer player	6 mg/kg	60 min.	Anhydrous	Test Batery	No effect
Lara et al., 2021	10 female	3 mg/kg	60 min.	Anhydrous	15 seconds Wingate	Beneficial
Richardson et al., 2016	9 resistance trained male	5 mg/kg	60 min.	Coffee and Anhydrous	60% of 1RM endurance	Beneficial
Skinner et al., 2019	11 female-16 male trained cyclists	3 mg/kg	90 min.	Anhydrous	Cycling time-trial	Beneficial
Wilk et al., 2019	15 resistance trained males	3, 6 and 9 mg/kg	60 min.	Anhydrous	Resistance exercise	No effect

CONCLUSION

- Athletes can ingest caffeine via different forms such as gum, coffee, anhydrous, and aerosol. Caution must be given that each form have different digestion duration and time to peak caffeine levels in blood.
- Although differences appears individually, caffeine seems to be effective 45-90 minutes after ingestion. Nevertheless, athletes should try its caffeine intake timing in trainings to see the outcomes.
- Most of the researches in literature showed caffeine as an ergogenic doses between 3 and 6 mg/kg of caffeine. However, lower doses of caffeine (<3 mg/kg) is still being investigated and depending on athletes' habitual caffeine consumption level, some athletes may benefit from low doses.
- Caffeine has been shown to increase aerobic-muscular endurance performance and sprint type activities. However, muscular strength and power responses has not been investigated much and existing studies reported generally negative results.
- Caffeine has also some beneficial effects after vigorous exercise as an recovery agent especially in glycogen stores.
- Body composition and hormonal differences between genders are apparent, but caffeine seems to increase physical and cognitive performance in both men and women. However, it would be helpful for female athletes to consider menstruel cycle while consuming caffeine as an ergogenic aid.
- Athletes' genotype can also have an impact on caffeine ergogenicity. It may be a requirement for athlete to be aware of caffeine ingestion increase performance depending on genotype in some studies. Preferably, genotype tests can be done to know which allels (AA or AC) athletes have.
- Considering caffeine may lead to side effects in some athletes, placebo effect can then be used in this situations because this has been found to effective on sports performance with no adverse effects.
- Most importantly, literature also focused on this topic, caffeine may improve performance depending on individuals' habitual caffeine consumption level. It can be suggested that athletes can increase acute caffeine intake dose higher than their habitually usage to exclude this tolerance phenomenon.

REFERENCES

1. Aguiar A.S., Speck, A.E., Canas, P.M., Cunha, R.A. (2020). Neuronal adenosine A_{2A} receptors signal ergogenic effects of caffeine. *Scientific Reports,* 10, 13414.
2. Akça, F., Aras, D., Arslan, E. (2018). Kafein, etki mekanizmaları ve fiziksel performansa etkileri. *Spormetre*, 16(1), 1-12.
3. Algrain Haya, A.T.R.M., Carrillo, A.E., Ryan, E.J., Chuk-ho, K., Lettan, R.B., Ryan, E.J. (2016). The effects of a polymorphism in the cytochrome P450 CYP1A2 gene on performance enhancement with caffeine in recreational cyclists. *Journal of Caffeine Research*, 6(1), 34-39.
4. Anderson, D.E., German, R.E., Harrison, M.E., Bourassa, K.N., Taylor, C.E. (2020). Real and perceived effects of caffeine on sprint cycling in experienced cyclists. *Journal of Strength and Conditioning Research*, 34(4), 929-933.
5. Apostolidis, A., Mougios, V., Smilios, I., Frangous, M., Hadjicharalambou, M. (2020). Caffeine supplementation is ergogenic in soccer players independent of cardiorespiratory or neuromuscular fitness levels. *Journal of the International Society of Sports Nutrition*, 17, 31.
6. Bayraktar, F., Taşkıran, A. (2019). Kafein tüketimi ve atletik performans. *Journal of Health and Sport Sciences,* 2(2), 24-33.
7. Bayram, H.M., Ozturkcan, S.A. (2020). Sporcularda ergojenik destekler. *Türkiye Klinikleri Sağlık Bilimleri Dergisi,* 5(3), 641-652.
8. Beaumont, R., Cordery, P., Funnell, M., Mears, S., James, L., Watson, P. (2017). Chronic ingestion of a low dose of caffeine induces tolerance to the performance benefits of caffeine. *Journal of Sports Sciences*, 35(19), 1920-1927.
9. Bell, D.G., Mclellan, T.M. (2002). Exercise endurance 1, 3, and 6 h after caffeine ingestion in caffeine users and nonusers. *Journal of Applied Physiology.* 93(4), 1227-1234.
10. Bottoms, L., Greenhalgh, A., Gregory, K. (2013). The effect of caffeine ingestion on skill maintenance and fatigue in epee fencers. *Journal of Sports Sciences,* 31(10), 1091-9.
11. Burke, L.M. (2017). Practical issues in evidence-based use of performance supplements: supplement interactions, repeated use and individual responses. *Sports Medicine,* 47, 79-100.
12. Cairns, S.P., Hing, W.A., Slack, J.R., Mills, R.G., Loiselle, D.S. (1997). Different effects of raised [K^+] on membrane potential and contraction in mouse fast and slow-twitch muscle. *American Journal of Physiology Cell Physiology*, 273,598-611.
13. Chia, J.S., Barrett, L.A., Chow, J.Y., Burns, S.F. (2017). Effects of caffeine supplementation on performance in ball games. *Sports Medicine,* 47(12), 2453-2471.
14. Childs, E., Hohoff, C., Deckert, J., Xu, K., Badner, J., With, H. (2008). Association between ADORA2A and DRD2 polymorphisms and caffeine-induced anxiety. *Neuropsychopharmacology,* 33(12), 1694-1702.
15. Christensen, P.M., Shirai, Y., Ritz, C., Nordborg, N.B. (2017). Caffeine and bicarbonate for speed. A meta-analysis of legal supplements potential for improving intense endurance exercise performance. *Frontiers in Physiology,* 8, 240.

16. Christopher, L., Hendy, A., Vanderwesthuizen, D., Teo, W.P. (2018). The modulation of corticospinal excitability and inhibition following acute resistance exercise in males and females. *European Journal of Sport Science,* 18(7), 984-993.
17. Clarke N, Baxter, H., Fajemilua, E., Jones, V., Oxford, S., Richardson, D.L., Wyatt, C., Mundy, P. (2016). Coffee and caffeine ingestion have little effect on repeated sprint cycling in relatively untrained males. *Sports.* 4, 45.
18. Clarke, N.D., Richardson, D.L., Thie, J., Taylor, R. (2018). Coffee ingestion enhances 1-mile running race performance. *Nutrients,* 13, 789-794.
19. Clarke, N.D., Kirwan, N.A., Richardson, D.L. (2019). Coffee ingestion improves 5 km cycling performance in men and women by a similar magnitude. *Nutrients*, 11, 2575.
20. Clarke, N.D., Richardson, D.L. (2016). Effect of coffee and caffeine ingestion on resistance exercise performance. *Journal of Strength and Conditioning Research.* 30(10), 2892-2900.
21. Cornelis, M.C. (2019). The impact of caffeine and coffee on human health. *Nutrients,* 11, 416.
22. Cruz, R.S.D.O., De Aguiar, R.A., Turnes, T., Guglielmo, L.G.A., Beneke, R., Caputo, F. (2015). Caffeine affects time to exhaustion and substrate oxidation during cycling at maximal lactate steady state. *Nutrients*, 7, 5254-5264.
23. Del Coso, J., Lara, B., Ruiz-Moreno, C., Salinero, J.J. (2019). Challenging the myth of non-response to the ergogenic effects of caffeine ingestion on exercise performance. *Nutrients,* 11, 732.
24. Denoeud, F., Carretero-Paulet, L., Dereeper, A., Droc, G., Guyot, R., Pietrella, M., Aury, J.M. (2014). The coffee genome provides insight into the convergent evolution of caffeine biosynthesis. *Science,* 345(6201), 1181-1184.
25. Doepker, C., Wikoff, D. (2018). Key findings and implications of a recent systematic review of the potential adverse effects of caffeine consumption in healthy adults, pregnant women, adolescents, and children. *Nutrients,* 10(10), 1536.
26. Duncan, M.J., Dobell, A.P., Caygill, C.L., Eyre, E., Tallis, J. (2019). The effect of acute caffeine ingestion on upper body anaerobic exercise and cognitive performance. *European Journal of Sport Science,* 19(1), 103-111.
27. Dunican, I.C., Higgins, C.C., Jones, M.J., Clarke, M.W., Murray, K., Dawson, B., Caldwell, J.A., Halson, S.L.,
28. Eastwood, P.R. (2018). Caffeine use in a super rugby game and its relationship to post – game sleep. *European Journal of Sport Science,* 18(4), 513-523.
29. El Yacoubi, M., Ledent, C., Menard, J.F., Parmentier, M., Costentin, J., Vaugeois, J.M. (2000). The stimulant effects of caffeine on locomotor behaviour in mice are mediated through its blockade of adenosine A (2A) receptors. *British Journal of Pharmacology,* 129(7), 1465-1473.
30. Ferre, S. (2016). Mechanisms of the psychostimulant effects of caffiene: implications for substance use disorder. *Psychopharmacology,* 233(10), 1963-1979.
31. Ferreira, T.T., Farrias Da Silva, J.V., Bueno, N.B. (2020). Effects of caffeine supplementation on muscle endurance, maximum strength, and perceived exertion in adults submitted to strength training: a systematic review and meta-analyses. *Critical Reviews in Food Science and Nutrition,* 61(15), 2587-2600.

32. Filip, A., Wilk, M., Krzytofik, M., Del Coso, J. (2020). Inconsistency in the ergogenic effect of caffeine in athletes who regularly consume caffeine: is it due to the disparity in the criteria that defines habitual caffeine intake?. *Nutrients,* 12, 1087.
33. Filip-Stachnik, A., Wilk, M., Krzytofik, M., Lulinska, E., Tufano, J.J., Zajac, A., Stastny, P., Del Coso, J. (2021). The effects of different doses of caffeine on maximal strength and strength-endurance in women habituated to caffeine. *Journal of International Society of Sports Nutrition,* 18(1), 25.
34. Foskett, A., Ali, A., Gant, N. (2009). Caffeine enhances cognitive function and skill performance during simulated soccer acitivity. *International Journal of Sports Nutrition and Exercise Metabolism,* 19(4), 410-423.
35. Gonçalves, L.S., Painelli, V.S., Yamaguchi, G., Oliveira, L.F., Saunders, B., Silva, R.P., Maciel, E., Artioli, G.G., Roschel, H., Gualano, B. (2017). Dispelling the myth that habitual caffeine consumption influences the performance response to acute caffeine supplementation. *Journal of Applied Physiology,* 123(1), 213-220.
36. Grgic J, Grgic I, Pickering C, Schoenfeld Bj, Bishop Dj, Pedisic Z (2019). Wake up and smell the coffee: caffeine supplementation and exercise performance-an umbrella review of 21 published meta-analyses. British Journal of Sports Medicine, 11: 681-688.
37. Grgic, J., Mikulic, P. (2020). Acute effects of caffeine supplementation on resistance exercise, jumping, and wingate performance: no influence of habitual caffeine intake. *European Journal of Sport Science, 21(8), 1165-1175.*
38. Graham, T.E. (2001). Caffeine and exercise: metabolism, endurance and performance. *Sports medicine,* 31(11), 785-807.
39. Guest, N., Corey, P., Vesconi, J., El-Sohemy, A. (2018). Caffeine, CYP1A2 genotype, and endurance performance in athletes. *Medicine and Science in Sport and Exercise,* 50(8), 1570-1578.
40. Guest, N.S., Vandusseldrop, T.A., Nelson, M.T., Grgic, J., Schoenfeld, B.J., Jenkinds, N.D.M., Arent, S.M., Antonio, J., Stout, J.R., Trexler, E.T., Smith-Ryan, A.E., Goldstein, E.R., Kalman, D.S., Campbell, B.I. (2021). International society of sport nutrition position stand: caffeine and exercise performance. *Journal of the International Society of Sports Nutrition,* 18(1), 1.
41. Hall, S., Desbrow, B., Anoopkumar-Dukie, S., Davey, A.K., Arora, D., Mcdermott, C., Grant, G.D. (2015). A review of the bioactivity of coffee, caffeine and key coffee constituents on inflammatory responses linked to depression. *Food Research International,* 76(3), 626-636.
42. Hunter, S.K. (2016). The relevance of sex differences in performance fatigability. *Medicine and Science in Sports and Exercise*, 48(11), 2247-2256.
43. Irwin, C., Desbrow, B., Ellis, A., O'Keeffe, B., Grant, G., Leveritt, M. (2011). Caffeine withdrawal and high-intensity endurance cycling performance. *Journal of Sports Sciences.* 29(5), 509-515.
44. Jeukendrup, A.E. (2017). Periodized nutrition for athletes. *Sports Medicine,* 47, 51-63.
45. Kaçoğlu, C. (2019). Adölesan kız hentbolcularda, düşük doz kahve tüketiminin anaerobik performansa akut etkileri. *Türkiye Klinikleri Spor Bilimleri Dergisi,* 11(3), 97-107.
46. Kamimori, G.H., Karyekar, C.S., Otterstetter, R., Cox, D.S., Balkin, T.J., Belenky, G.L., Eddington, N.D. (2002). The rate of absortion and relative bioavailability of caffeine administered in chewing gum

versus capsules to normal healthy vounteers. *International Journal of Pharmaceutics*, 234(1-2), 159-167.

47. Kara, Z., Taşkın, H., Erkmen, N., Baştürk, D. (2019). Kafein takviyesinin kısa süreli yüksek yoğunluklu egzersize etkisi: kafein alım zamanı. *Spor ve Performans Araştırmaları Dergisi,* 10(1), 31-43.
48. Karayigit, R., Naderi, A., Akça, F., Gomez Da Cruz, C.J., Sarshin, A., Yasli, B.C., Ersöz, G., Kaviani, M. (2021). Effects of different doses of caffeinated coffee on muscular endurance, cognitive performance and cardiac autonomic modulation in caffeine naive female athletes. *Nutrients*, 13, 2.
49. Lara, B., Ruiz-Moreno, C., Salinero, J.J., Del Coso, J. (2019). Time course of tolerance to the performance benefits of caffeine. *Plos One*, 14(1), e0210275.
50. Lara, B., Salinero, J.J., Giraldez-Costos, V., Del Coso, J. (2021). Similar ergogenic effect of caffeine on anaerobic performance in men and women athletes. *European Journal of Nutrition,* online ahead of print.
51. Liebherman, H.R., Tharion, W.J., Shukitt-Hale, B., Speckman, K.L., Tulley, R. (2002). Effects of caffeine, sleep loss and stress on cognitive performance and mood during U.S. Navy Seal training. *Psychopharmacology,* 164(3), 250-261.
52. Magkos, F., Kavarous, S.T. (2005). Caffeine use in sports, pharmacokinetics in man, and cellular mechanisms of action. *Critical Reviews in Food Science and Nutrition*. 45(7-8), 535-562.
53. Marcil, M., Karelis, A.D., Peronet, F., Gardier, P.F. (2005). Glucose infusion attenuates fatigue without sparing glycogen in rat soleus muscle during prolonged electrical stimulation in situ. *European Journal of Applied Physiology,* 93(5-6), 569-574.
54. Martins, G.L., Guilherme, J.P.L.F., Ferreira, L.H.B., Souza-Junior, T.P., Lancha, A.H. (2020). Caffeine and exercise performance: possible directions for definitive findings. *Frontiers in Sports and Active Living, 2,* 574854.
55. Mattson, M.P. (2012). Evolutionary aspects of human exercise-born to run purposefully. *Ageing Research Reviews,* 11(3), 347-352.
56. Maughan, R.J., Burke, L.M., Dvorak, J., Larson-Meyer D.E., Peeling, P., Philips, S.M. (2018). IOC consensus statement: dietary supplements and the high-performance athlete. *International Journal of Sport Nutrition and Exercise Metabolism*, 28(2), 104-125.
57. Mclellan, T.M., Kamimori, G.H., Voss, D.M., Tate, C., Smith, S.J. (2007). Caffeine effects on physical and cognitive performance during sustained operations. *Aviation Space Environmental Medicine,* 78(9), 871-877.
58. Mclellan, T.M., Caldwell, J.A., Liebherman, H.R. (2016). A review of caffeine's effects of cognitive, physical and occupational performance. *Nueroscience&Biobehavioral reviews,* 71, 294-312.
59. Mielgo-Ayuso, J., Marques-Jimenez, D., Refoyo, I., Del Coso, J., Leon-Guereno, P., Calleja-Gonzalez, J. (2019). Effect of caffeine supplementation on sports performance based on differences between sexes: a systematic review. *Nutrients,* 11, 2313.
60. Mohr, M., Nielsen, J.J., Bangsbo, J. (2011). Caffeine intake improves intense intermittent exercise performance and reduces muscle interstitial potassium accumulation. *Journal of Applied Physiology,* 111(5), 1372-1379.

61. Ogawa, N., Ueki, H. (2007). Clinical importance of caffeine dependence and abuse. *Psychiatry Clin Neurosci,* 61(3), 263-268.
62. Ou-Yang, D.S., Huang, S.L., Wang, W. (2000). Phenotypic polymorphism and gender-related differences of CYP1A2 activity in a Chinese population. *British Journal of Clinical pharmacology,* 49(2), 145-151.
63. Ryan, E.J., Kim, C.H., Fickes, E.J., Williamson, M., Muller, M.D., Barkley, J.E. (2013). Caffeine gum and cycling performance: a timing study. *Journal of Strength and Conditioning Research,* 27(1), 259-264.
64. Pallares, J.G., Fernandez-Elias, V.E., Ortega, J.F., Munoz, G., Munoz-Guerra J., Mora-Rodriguez, R. (2013). Neuromuscular responses to incremental caffeine doses: performance and side effects. *Medicine and Science in Sport and Exercise,* 45(11), 2184-2192.
65. Pataky, M.W., Womack, C.J., Saunders, M.J., Goffe, J.L., D'Lugos, A.C., El-Sohemy, A. (2016). Caffeine and 3-km cycling performance effects of mouth rinsing, genotype, and time of day. *Scandinavian Journal of Medicine and Science in Sports,* 26(6), 613-619.
66. Pickering, C., Grgic, J. (2019). Caffeine and exercise: what next?. *Sports Medicine,* 49(7), 1007-1030.
67. Pickering, C., Grgic, J. (2021). A time and a place: a framework for caffeine periodization throughout the sporting year. *Nutrition,* 82, 111046.
68. Pickering, C., & Kiely, J. (2019). Do non-responders to exercise exist—and if so, what should we do about them?. Sports Medicine, 49(1), 1-7.
69. Pontifex, K.J., Wallman, K.E., Dawson, B.T., Goodman, C. (2010). Effects of caffeine on repeated sprint ability, reactive agility time, sleep and next day performance. *Journal of Sports Medicine and Physical Fitness,* 50(4), 455-464.
70. Ruiz-Moreno, C., Lara, B., Gutierrez-Hellin, J., Gonzalez-Garcia, J., Del Coso, J. (2020). Time course and magnitude of tolerance to the ergogenic effect of caffeine on the second ventilatory threshold. *Life,* 10(12), 343.
71. Ryan Ej, Kım Ch, Fıckes Ej, Wılliamson M, Muller Md, Barkley Je (2013). Journal of Strength and Conditioning Research, 27: 259-264.
72. Sabblah, S., Dizon, D., Bottoms, L. (2015). Sex differences on the acute effects of caffeine on maximal strength and muscular endurance. *Comperative Exercise Physiology,* 11(2), 89-94.
73. Salinero, J., Jimenez-Ormeno, E., Romero-Moraleda, B., Giraldez-Costas, V., Baltazar-Martins, G., Del Coso, J. (2019). More research is necessary to establish the ergogenic effect of caffeine in female athletes. *Nutrients,* 11, 1600.
74. Shen, JG, Brooks, M.B., Cincotta, J., Manjourides, J.D. (2019). Establishing a relationship between the effect of caffeine and duration of endurance athletic time trial events: a systematic review and meta-analysis. *Journal of Science and Medicine in Sport,* 22(2), 232-238.
75. Skinner, T.L., Desbrow, B., Arapova, J., Schaumberg, M.A., Osborne, J., Grant, G.D., Aanookumar-Dukie, S., Leveritt, M.D. (2019). Women experience the same ergogenic response to caffeine as men. *Medicine and Science in Sport and Exercise,* 51(6), 1195-1202.
76. Southward, K., Rurtherfurd-Markwick, K.J., Ali, A. (2018). The effect of acute caffeine ingestion on endurance performance: a systematic review and meta-analysis. *Sports Medicine,* 48(8), 1913-1928.

77. Spriet, L.L. (2014). Exercise and sport performance with low doses of caffeine. *Sports Medicine*, Suppl 2, 175-184.
78. Stuart, G.R., Hopkins, W.G., Cook, C., Cairns, S.P. (2005). Multiple effects of caffeine on simulated high-intensity team-sport performance. *Medicine and Science in Sports and Exercise*, 37(11), 1998-2005.
79. Taylor, C., Higham, D., Close, G.L., Morton, J.P. (2011). The effect of adding caffeine to postexercise carbohydrate feeding on subsequent high-intensity interval-running capacity compared with carbohydrate alone. *International Journal of Sport Sutrition and Exercise Metabolism*, 21(5), 410-416.
80. Tepper, J.M., Wilson, C.J., Koös, T. (2008). Feedforward and feedback inhibition in neostriatal GABAergic spiny neurons. *Brain Research Reviews*, 58(2), 272-281.
81. Thibault, V., Guillaume, M., Berthelot, G., El Helou, N., Schaal, J., Quinquis, L., Nassif, H., Tafflet, M., Escolano, S., Hermine, O. (2010). Women and men in sport performance: the gender gap has not evolved since 1983. *Journal of Sports Science and Medicine*, 9(2), 214-223.
82. Trexler, E.T., Smith-Ryan, A.E., Roelofs, E.J., Hirsch, K.R., Mock, M.G. (2015). Effects of coffee and caffeine anhydrous on strength and sprint performance. *European Journal of Sport Science.* 16(6), 702-710.
83. Ulucan, K., Sercan, C., Eken B.F., Ulgut, D., Erel, S. (2016). Spor genetiği ve ace gen ilişkisi. *İnönü Üniversitesi Beden Eğitimi ve Spor Bilimleri Dergisi,* 3(2), 26-34.
84. Warren, G.L., Park, N.D., Maresca, R.D., Mckibans, K.I., Millard-Stafford, M.L. (2010). Effect of caffiene ingestioon muscular strength and endurance: a meta-alalysis. *Medicine and Science in Sport and Science.* 42(7), 1375-1387.
85. Wilk, M., Filip, A., Krzsytofik, M., Maszczy, A., Zajac, A. (2019). The acute effect of various doses of caffeine on power output and velocity during the bench press exercise among athletes habitually using caffeine. *Nutrients*, 11, 1465.
86. Womack, C.J., Saunders, M.J., Bechtel, M.K., Bolton, D.J., Martin, M., Luden, N.D. (2012). The influence of a CYP1A2 polymorphism on the ergogenic effects of caffeine. *Journal of International Society of Sport Nutrition,* 9(1), 438-452.
87. Van Thuyne, W., Delbeke, F.T. (2006). Distribution of caffeine levels in urine in different sports in relation to doping control before and after the removal of caffeine from the WADA doping list. *International Journal of Sports Medicine,* 27(9), 745-750.
88. Yang, C., Franciosi, S., Brown, R.E. (2013). Adenosine inhibits the excitatory synaptic inputs to basal forebrain cholinergic, GABAergic, and parvalbumin neurons in mice. *Frontiers in Neurology,* 4, 77.
89. Zhan, B., Liu, Y., Wang Xiaochun, W., Deng, Y., Zheng, X. (2020). Cognition and brain activation in response to various doses of caffeine: a near-infrared spectroscopy study. *Frontiers in Psychology,* 11, 1393.

Performance Analysis in Sport and Exercise

Ankara University Performance Analysis in Sports Application and Research Center

Available online 5 December 2022

Investigation of Relationships Between Tennis Serve Performance, Anthropometry, Somatotype and Range of Motion According to Sex

Mustafa Can Eser [1 *]
[1] Faculty of Sport Sciences, Ankara University, Ankara, Turkey

Abstract

Serve is one of the most important strokes of tennis. The aim of the study is to examine relationships between anthropometric features, shoulder range of motion (ROM), somatotype and serve performance (serve accuracy & serve speed) according to sex. 15 male (age: 19.00 ± 1.06 years) and 14 female (age: 18.64 ± 0.92 years) tennis players participated in this study. The descriptive and anthropometric measurements (age, competitive experience, height, body mass, body mass index, arm & wrist circumferences) and ROM (internal & external shoulder rotation degrees) were taken and recorded. Somatotype determined based on Heart Carter method. In order to determine serve performance, a pre-designated test, which evaluates serve speed and accuracy for both "first serve and "second serve" carried out. The Pearson's coefficient of correlation was used to study the correlation between serve performance and the anthropometric, somatotype and ROM variables. Student's t-test was used to comparison of sexes. To compare correlations coefficients among sexes, Fisher's z transformation performed. As hypothesized, results showed that serve performance determinants were differ according to sex.

Key Words: Serve speed, serve accuracy, shoulder ROM, gender comparison

INTRODUCTION

Tennis is one of the most popular sports worldwide for both professionals and recreational players (18). In the last two decades, tennis has evolved into a more speed, power and strength-based sport (13). With this progression, the importance of serve, the most strength-demanding stroke in tennis has increased (15). Since serving in the aimed area is important for reducing the effectiveness of the opponent's offensive and defensive systems during the game, a good serve may be consider as one of most important factors of an efficient attack (11).

To date, many studies conducted to investigate determinants of serve performance (1, 5, 7, 14, 17, 24). These studies mainly reported anthropometric features, upper extremity strength, hip, wrist and shoulder rotation are some determinants of serve performance. Besides, previous studies demonstrated that serve speed is influenced by player's experience (14). There are also findings about physical and morphological profiling tennis players may contribute development of more specific attributes (2, 8, 10, 23). Within the research investigating the tennis serve kinematics, some researchers have focused on the lower/upper body joints as well as the movement of the racquet (4, 6); while others have investigated the relationship between some specific joint kinetics and serving performance (9, 19, 22, 25). Although previous studies have reported determinants of serve performance, there is a scarcity of studies examining these determinants sex-wise.

Besides scarcity of gender studies, above-mentioned studies mostly investigated determinants of "first serve". However, the first and second serve are strokes with different characteristics. While first serves faster, inconsistent and includes slight spins; seconds serves are slower but more accurate and involving sidespins. Therefore, these two serve manners expected to have different needs.

The purpose of this study was to investigate the relationships between serve performance (i.e. serve speed & accuracy) and anthropometric, somatotype shoulder ROM and compare these correlations among sexes. Results of the study may contribute to the knowledge of serve performance for players and coaches.

METHODS

Study Design

This was a descriptive, cross-sectional study. The population of study included college level Turkish male and female tennis players.

Subjects

The sample consisted of 29 tennis players (15 male & 14 female). The inclusion criteria were attending tennis competitions for at least 5 years, training at least eight hours a week and being healthy. Descriptive data of participants have represented in table 1. All the participants have briefed about testing protocols.

Table 1. Descriptive data.

	Male	Female	t	p
Age (years)	19.00 ± 1.06	18.64 ± 0.92	0.957	0.347
Height (cm)	176.70 ± 4.44	168.61 ± 4.68	4.771	**0.000**
Competition Experience (years)	6.66 ± 1.44	6.57 ± 1.91	0.152	0.880
Body Mass (kg)	70.30 ± 4.51	59.41 ± 5.43	5.881	**0.000**
BMI (index)	22.51 ± 1.20	20.84 ± 0.86	4.262	**0.000**

Procedures

All tests were performed in two different days. At first day, participants' anthropometric, somatotype and ROM data were collected. At the second day serve test was carried out. Measures of anthropometric characteristics were represented by 7 variables, these being: body height (cm), forearm length (cm), upper arm length (cm), wrist circumference (cm), arm circumference (cm), body mass (kg), body mass index (index). Internal and external rotation angles were collected as shoulder ROM variables. The somatotype values of the participants were determined using Heath Carter method of somatotyping (3).

At the first day, each participant's body height was measured with a fixed stadiometer (Holtain, England) and bodyweight measured by a scale with bioelectrical impedance analyzer (Tanita, TBF 401A, Japan). After that, forearm & upper arm length and wrist & arm circumference measurements carried out consecutively with a measurement tape. For the wrist circumference, tape is applied around the wrist while not applying any pressure to the distal to the styloid processes of the radius and ulna. The ROM measurements carried out with a goniometer by an experienced physiotherapist with standard methods. Based on Heart Carter (3) method, body weight, height, biceps and calf circumference during flexion, humerus and femur breadth, triceps, subscapular, suprailiac and calf skinfold were measured and the formula used to calculate somatotype values. All measurements were performed before noon.

The serve test was performed on a standard indoor clay tennis court. Participants were free to use their own racquets in order to avoid familiarization related issues. After 10 minutes of individual warm up session, participants instructed to perform in total 40 serves to two pre-designated targets on each serve boxes. 20 first serve and 20 second serve for both right and left serve boxes were executed according to player's choice. Two observers; one of them behind serve-side long line and the other one behind baseline checked if the serve is "in" or "out". Between trial rest intervals given as much as players want. During each trial, participants used newly opened balls (Wilson US Open, Wilson Sporting Goods Co, Chicago, IL, USA). Serve speed measured by a radar gun (Speed Gun SR3600, Sports Radar, FL, USA).

Statistical Analyses

All data were analyzed using statistical software (IBM SPSS Statistics 20, IBM, USA) with the level of significance set at $p<0.05$ Normality of data was checked by Shapiro-Wilk test ($p<0.05$). The Pearson's coefficient of correlation was used to study the correlation between serve performance and the anthropometry, somatotype and ROM variables. Student's t-test was used to comparison of sexes. To compare correlations coefficients among sexes, Fisher's z transformation performed.

FINDINGS

Table 2. Serve, Anthropometry, ROM, Somatotype data.

	Male (Mean ± St. D.)	Female (Mean ± St. D.)	t	p
First Serve Speed (km/h)	167. 28 ± 8.91	149.58 ± 12.51	4.409	**0.000**
First Serve Accuracy (score)	0.52 ± 0.14	0.50 ± 0.08	0.356	0.725
Second Serve Speed (km/h)	133.34 ± 8.19	117.09 ± 10.44	4.679	**0.000**
Second Serve Accuracy (score)	0.71 ± 0.11	0.71 ± 0.07	-0.128	0.899
Upper Arm Length (cm)	30.34 ± 1.66	27.39 ± 0.90	5.868	**0.000**
Forearm Length (cm)	29.66 ± 2.02	25.70 ± 0.66	6.953	**0.000**
Wrist Circumference (cm)	15.97 ± 1.20	15.25 ± 1.20	1.606	0.120
Arm Circumference (cm)	29.12 ± 2.28	25.57 ± 1.26	5.121	**0.000**
Internal Shoulder Rotation (deg)	43.00 ± 2.09	41.08 ± 1.08	3.052	**0.005**
External Shoulder Rotation (deg)	125.00 ± 3.25	121.88 ± 1.92	3.119	**0.004**
Endomorphy	1.66 ± 0.89	1.71 ± 0.46	-0.177	0.861
Mesomorphy	2.80 ± 0.94	1.92 ± 0.73	2.772	0.010
Ectomorphy	3.53 ± 1.12	4.14 ± 0.86	-1.627	0.115

The findings observed separately for all four serve conditions. For male participants first serve speed, there was no correlation observed except BMI ($r=-0.69$, $p<0.05$). However, height ($r=0.53$, $p<0.05$) upper arm length ($r=0.61$, $p<0.05$) and arm circumference ($r=0.80$, $p<0.01$) was significantly correlated for females. First serve accuracy of male correlated with arm circumference ($r=-0.60$, $p<0.05$), internal shoulder rotation ($r=0.67$, $p<0.05$), endomorphy ($r=-0.76$, $p<0.01$) and ectomorphy ($r=0.65$, $p<0.05$). First serve accuracy of females correlated with height ($r=0.58$, $p<0.05$), competition experience ($r=0.69$, $p<0.05$), body mass ($r=0.53$, $p<0.05$) and internal rotation ($r=0.79$, $p<0.01$).

Table 3. First serve performance correlations.

	First Serve Speed				First Serve Accuracy			
	Female	**Male**	z	p	**Female**	**Male**	z	p
Age	-0.20	0.37	-	-	-0.17	0.00	-	-
Height	**0.53***	0.36	-	-	**0.58***	0.34	-	-
Competition Experience	0.31	-0.07	-	-	**0.69***	0.37	-	-
Body Mass	0.46	-0.27	-	-	**0.53***	0.28	-	-
BMI	0.32	**-0.69***	-	-	0.39	0.00	-	-
Upper Arm Length	**0.61***	0.27	-	-	0.32	0.28	-	-
Forearm Length	0.09	0.12	-	-	0.01	0.24	-	-
Wrist Circumference	-0.27	-0.25	-	-	-0.52	**-0.60***	-	-
Arm Circumference	**0.80****	-0.26	-	-	0.40	0.02	-	-
Internal Shoulder Rotation	0.39	0.05	-	-	**0.79****	**0.67***	0.62	0.535
External Shoulder Rotation	-0.08	0.34	-	-	0.38	0.40	-	-
Endomorphy	0.01	-0.07	-	-	0.02	**-0.76****	-	-
Mesomorphy	-0.12	-0.46	-	-	-0.11	-0.40	-	-
Ectomorphy	0.45	0.14	-	-	0.49	**0.65***	-	-

** p<0.01 *p<0.05 for correlation coefficients

Second serve speed of males correlated with only wrist circumference (r=-0.59, p<0.05) and there is no correlation in females for this condition. Second serve accuracy is correlated with height (r=0.56, p<0.05), wrist circumference (r=-0.86, p<0.01), internal shoulder rotation (r=0.69, p<0.01), endomorphy (r=-0.72, p<0.01), ectomorphy (r=0.84, p<0.01) for males. Lastly, second serve accuracy is correlated with height (r=0.56, p<0.05), competition experience (r=0.61, p<0.05), body mass (r=0.57, p<0.05), wrist circumference (r=-0.56, p<0.05), internal shoulder rotation (r=0.77, p<0.01), ectomorphy (r=0.63, p<0.05). The z-transformation only applied when significant correlations were observed for both sexes in same variable as explained in statistical analyses section. As calculated transformed scores shown, there is no difference between any of related correlations (z= -1.15 to 1.58; p>0.05).

Table 4. Second serve performance correlations.

	Second Serve Speed				Second Serve Accuracy			
	Female	**Male**	z	p	**Female**	**Male**	z	p
Age	-0.17	0.07	-	-	-0.35	-0.14	-	-
Height	0.12	0.08	-	-	**0.56***	**0.56***	0.00	1.000
Competition Experience	0.14	-0.17	-	-	**0.61***	0.38	-	-
Body Mass	0.02	0.21	-	-	**0.57***	0.44	-	-
BMI	-0.09	0.19	-	-	0.52	0.00	-	-
Upper Arm Length	0.34	0.42	-	-	0.12	0.50	-	-
Forearm Length	-0.22	0.27	-	-	-0.04	0.49	-	-
Wrist Circumference	-0.25	**-0.59***	-	-	**-0.56***	**-0.86****	1.58	0.114
Arm Circumference	0.46	0.00	-	-	0.49	0.15	-	-
Internal Shoulder Rotation	0.31	0.12	-	-	**0.77****	**0.69****	0.62	0.535
External Shoulder Rotation	0.05	-0.05	-	-	0.39	0.48	-	-
Endomorphy	0.36	-0.43	-	-	0.04	**-0.72****	-	-
Mesomorphy	-0.30	-0.05	-	-	-0.47	-0.47	-	-
Ectomorphy	0.06	0.49	-	-	**0.63***	**0.84****	-1.15	0.250

** p<0.01 *p<0.05 for correlation coefficients

DISCUSSION

To best of our knowledge, current study is the first study that investigate serve performance determinants according to sex. The primary finding of this study is that serve performance determinants are differ by sex. The results of study will be discussed under anthropometric features, somatotype and ROM subheadings.

Anthropometric Features

When we examine correlations of anthropometrics with speed, while four moderate to strong significant correlations observed for first serve (height, upper arm length, arm circumference and BMI), there is only one (wrist circumference) correlation observed for second serve. Therefore, we can state that first serve speed is more dependent to anthropometric features according to second serve speed. To be more specific, female players' height, upper arm length and arm circumference & male players' BMI moderately correlated with first serve speed. Nevertheless, none of these correlations is common for both sexes. Thus, we can state that first serve speed determinants are different for male and female players.

Since BMI of the participants in the study was found to be 20.84 ± 0.86 & 22.51 ± 1.20 for females and males respectively, it was observed that it was within normal range (16). In our study BMI correlated with first serve speed in males (r= -0.69). Former studies also found and explained similar negative correlation between BMI and serve speed by possible effects of greater muscle mass and consequent greater strength (10). In line with those explanations, we used arm circumference as strength indicator and found a positive correlation with females first serve speed (r= 0.80). While previous studies observed positive correlation with peak serve speed (12, 24) and body height, we did not observe such correlation. The authors explained above-mentioned correlations by a mechanism, which offers body height and limb length correlated therefore contributes serve speed. Our upper arm length finding in females (r=0.61) may possibly support this point of view in addition to our body height and serve speed findings (r=0.53).

Somatotype

Contrary to the literature, our subjects were dominantly ectomorph (20, 21). Current study showed that somatotype is a great determinant of serve accuracy especially for male players. Ectomorphy and serve accuracy are moderately (r=0.65) and strongly (r=0.84) correlated for male players in both first and second serve conditions respectively. Besides, there are negative strong correlations (r=-0.72, r= 0.76) among endomorphy and accuracy only in males. The accuracy of ectomorphs may be explained by their ability to make finer movements during wrist-snap phase of serve. In line with literature, somatotype found to be not correlated with serve speed in our study too (10, 20).

ROM

The main finding in ROM section is that while internal rotation strong indicator of accuracy level for both sexes (r=0.67-0.79) and there is no correlation between external rotation and any serve performance parameter. and these findings are in line with a previous study which investigates ROM and serve performance relationship in a wide scope (17).

We assessed shoulder ROM with only internal and external rotation because of time limitations. Also, menstrual cycles of female participants -which may directly affect explosive strength- did not followed. We let players use their own racquets in order to avoid familiarization related problems. Therefore, future studies can examine effect of racquet-related variables such as string tension, string type and racquet weight.

CONCLUSION

This study is original in sex comparison of serve performance determinants context. The main finding of study is that serve performance determinants are generally differ by sex. From this aspect, current study provides a correlation analysis across players' tennis serve, anthropometrics, ROM and somatotype, which may contribute to the knowledge of serve performance for players and coaches. However, it should be noted that serve is one of most complex strokes in tennis so there are many indicators may possibly effect serve performance than evaluated in this study.

ACKNOWLEDGEMENTS

The researcher thanks to all players for their honest efforts and participation.

Funding: This research received no external funding.

Conflicts of Interests: The author declares no conflict of interest.

REFERENCES

1. Bonato M, Maggioni M, Rossi C, Rampichini S, La Torre A, and Merati G. Relationship between anthropometric or functional characteristics and maximal serve velocity. *J Sport Med Phys Fitness* 55: 1157-1165, 2015.
2. Buti T, Elliott B, and Morton A. Physiological and anthropometric profiles of elite prepubescent tennis players. *The Physician and Sportsmedicine* 12: 111-116, 1984.
3. Carter JL, Carter JL, and Heath BH. *Somatotyping: development and applications.* Cambridge university press, 1990.
4. Chow J, Carlton L, Lim Y-T, Chae W-S, Shim J-H, Kuenster A, and Kokubun K. Comparing the pre-and post-impact ball and racquet kinematics of elite tennis players' first and second serves: a preliminary study. *Journal of sports sciences* 21: 529-537, 2003.
5. Cohen DB, Mont MA, Campbell KR, Vogelstein BN, and Loewy JW. Upper extremity physical factors affecting tennis serve velocity. *The American Journal of Sports Medicine* 22: 746-750, 1994.
6. de Subijana CL and Navarro E. Kinetic energy transfer during the serve. *Journal of Human Sport and Exercise* 4: 114-128, 2009.
7. Ellenbecker T and Roetert E. Velocity of a tennis serve and measurement of isokinetic muscular performance: brief review and comment. *Perceptual and motor skills* 98: 1368-1370, 2004.
8. Fernandez-Fernandez J, Ulbricht A, and Ferrauti A. Fitness testing of tennis players: How valuable is it? *British journal of sports medicine* 48: i22-i31, 2014.
9. Fleisig G, Nicholls R, Elliott B, and Escamilla R. Tennis: Kinematics used by world class tennis players to produce high-velocity serves. *Sports Biomechanics* 2: 51-64, 2003.
10. Gale-Watts AS and Nevill AM. From endurance to power athletes: The changing shape of successful male professional tennis players. *European Journal of Sport Science* 16: 948-954, 2016.
11. Gencer YG and Beyza Ö. An Analysis On The Relationship Between Serving Strength And Anthropometric Properties And Tennis Serving Success In Young Women Volleyball Players. *Turkish Journal of Sport and Exercise* 22: 183-188, 2020.
12. Hayes MJ, Spits DR, Watts DG, and Kelly VG. Relationship between tennis serve velocity and select performance measures. *The Journal of Strength & Conditioning Research* 35: 190-197, 2021.
13. Kovacs MS. Tennis physiology. *Sports medicine* 37: 189-198, 2007.
14. Martin C, Bideau B, Ropars M, Delamarche P, and Kulpa R. Upper limb joint kinetic analysis during tennis serve: Assessment of competitive level on efficiency and injury risks. *Scandinavian journal of medicine & science in sports* 24: 700-707, 2014.
15. Martin C, Kulpa R, Delamarche P, and Bideau B. Professional tennis players' serve: correlation between segmental angular momentums and ball velocity. *Sports Biomechanics* 12: 2-14, 2013.
16. Organization WH. Obesity: preventing and managing the global epidemic. 2000.
17. Palmer K, Jones D, Morgan C, and Zeppieri Jr G. Relationship between range of motion, strength, motor control, power, and the tennis serve in competitive-level tennis players: A pilot study. *Sports health* 10: 462-467, 2018.

18. Pluim BM, Miller S, Dines D, Renström PA, Windler G, Norris B, Stroia KA, Donaldson A, and Martin K. Sport science and medicine in tennis. *British Journal of Sports Medicine* 41: 703-704, 2007.
19. Reid M, Elliott B, and Alderson J. Shoulder joint kinetics of the elite wheelchair tennis serve. *British journal of sports medicine* 41: 739-744, 2007.
20. Sanchez-Munoz C, Sanz D, and Zabala M. Anthropometric characteristics, body composition and somatotype of elite junior tennis players. *British journal of sports medicine* 41: 793-799, 2007.
21. Söğüt M and Altunsoy K. Physical and Morphological Characteristics of Turkish National Adolescent Tennis Players and Their Association with Serve Speed. *Spor Hekimligi Dergisi/Turkish Journal of Sports Medicine* 54, 2019.
22. Tanabe S and Ito A. Application of the extrapolation method to motion analysis of the flat power serve in tennis. *International Journal of Sport and Health Science* 5: 157-167, 2007.
23. Ulbricht A, Fernandez-Fernandez J, Mendez-Villanueva A, and Ferrauti A. Impact of fitness characteristics on tennis performance in elite junior tennis players. *The journal of strength & conditioning research* 30: 989-998, 2016.
24. Vaverka F and Cernosek M. Association between body height and serve speed in elite tennis players. *Sports Biomechanics* 12: 30-37, 2013.
25. Whiteside D, Elliott B, Lay B, and Reid M. A kinematic comparison of successful and unsuccessful tennis serves across the elite development pathway. *Human Movement Science* 32: 822-835, 2013.

ASPAM
PERFORMANCE ANALYSIS IN SPORTS
Application and Research Center

Performance Analysis in Sport and Exercise

Ankara University Performance Analysis in Sports Application and Research Center

Available online 5 December 2022

Comparison of the Home-Court Performances of Successful and Unsuccessful Teams at Euroleague Before and After Covid-19 Pandemic

Tugay Durmuş [1*], Mehmet Gülü [2]
[1] Faculty of Sport Sciences, Ankara University, Ankara, Turkey
[2] Faculty of Sport Sciences, Kırıkkale University, Kırıkkale, Turkey

Abstract

Home advantage is defined as teams having a higher chance of winning in games played at home and is an often researched topic in team sports and basketball. Some situations, such as fan support, away team travel and environment familiarity, can increase home teams' chances of winning while playing at home. Having a higher winning rate at home games is one of the important determinants of the season-long success of the teams. This study aimed to compare home game performances of Euroleague’s successful and unsuccessful home teams, while they play in front of the fans in 2018-2019 season, and they play without fans in 2020-2021 season. Results of our study have similar findings with literature: Higher wins, higher points per game, lower loses and lower turnovers for home teams while they play in front of home crowds in the Euroleague. Our study showed a great impact of fans on home team’s performance in Euroleague but further research is needed to understand other dimensions of home advantage in basketball.

Key Words: Home advantage, basketball, fan support

INTRODUCTION

Home court advantage is defined as sports teams being closer to winning when playing on their home courts. The level of comfort that comes with playing in a familiar environment is thought to help increase the home team's chances of winning (28). It has been thought that one of the determining factors of season performances in team sports is the home court advantage and has been widely studied in basketball (7, 10), football (3, 18), baseball (11) and volleyball (2, 17). Some researchers argue that there is a real home advantage in sports (22), although some indicates a need of more studies to prove this assumption (32). However, in some situations, teams can achieve home court advantage in basketball. In competitions like Euroleague, in the playoffs (best of 3, 5, or 7 game series), teams can play more games at home. Teams have to have a higher regular season ranking than their opponents to gain home court advantage in playoffs.

Schwartz and Barsky (24), noted three primary sources of home advantage in sports: learning factors, travel (fatigue) factors, and crowd factors. They explain that the home team is more accustomed to their own court and arena conditions, (rims, playing surface, lighting, etc.). Traveling of the opposing team before the match can also contribute to the home court advantage. Some factors, such as the duration and type of travel, can increase the opposing team's fatigue level. This can cause performance degradation. Lastly, spectators can influence the outcome of a competition too by influencing the performance and the referees.

Quinn, et al. (21), suggested that playing in a different arena or court may have a negative effect on performance because familiarity is lower for visiting teams. Several studies noted that crowd size and fan attendance also increase the chances of the home team winning (1, 12, 31). Nevill, et al. (16) found a significant correlation between the home team's winning chance and crowd size. Harville and Smith (9) mathematical approach claims an estimated $4{,}68 \pm 0{,}28$ points advantage for home teams. One study has found that players have lower anxiety levels and higher self-confidence levels in home games than in away games (27). It is thought that when players have higher self-confidence, they are more likely to perform at higher levels and thus the team's chances of winning will increase. Yi (32) argued that fan support is a factor that holds a positive psychological effect on players.

The home advantage may also result from the away team traveling before the competition. The away team has probably played the previous game and travelled in the last few days. The assumption that travel, fatigue, and disruption of routines will harm the performance of athletes has been studied by several authors. Frequent air travel can adversely affect hydration, nutritional behaviours, sleep quality and quantity. These types of disorders can cause athletes to not recover properly after training or games (13). When traveling to two or more time zones, symptoms of travel fatigue may persist up to 2-3 days after travel (23). Flying in one or more time zones can also change sleep patterns in athletes (4). A 72-hour recovery window following matches and practice is required for an athlete or team to return to optimal performance levels (15). However, in leagues such as Euroleague and NBA, optimal recovery cannot be achieved because teams play an average of three games in seven days. This can cause decreased performance and an increased risk of injury.

It is also thought that the fans can help the home team to win by putting pressure on the referees. Sutter and Kocher (26) found that the referees made partial decisions in favour of the home teams. They explained that this could be an unintended reaction caused by the influence of the home team's fans on the referees. Price, et al. (19) also presented similar findings proving that NBA referees also tend to decide in favour of the home team.

The COVID-19 pandemic has caused many sports organizations to be suspended, cancelled or continued in different isolated venues in the world. Since basketball is played indoors with thousands of spectators in stands, it has been one of the sports most affected by this pandemic. The remaining games had to be played on neutral venues without any spectators, extra precautions were taken during travels and the players was constantly tested for COVID-19 during this process. It is thought that playing the matches in neutral venues without spectators affects the home advantage. Examining the statistical changes in the games played in the home court before and after the COVID-19 pandemic can be used to examine the effects of the fans on team’s performance. Thus, this study aimed to evaluate the home court performances of successful and unsuccessful teams in the Euroleague before and after the COVID-19 pandemic.

METHODS

Study Design

In the 2018/2019 and 2020/2021 regular seasons, the 5 teams that won the most games at home (defined as successful) and the 5 teams that won the least games (defined as unsuccessful) were included in the scope of this research. In Euroleague, teams played a total of 15 home games in the 2018-2019 regular season and total of 17 home games in 2021-2021 regular season. The statistical categories used to compare teams' home success were: Wins (W), loses (L), points scored per game (PTS), two points percentage per game (2PT%), three points percentage per game (3PT%), field goals mad per game (FGM), field goals attempts per game (FGA), field goal percentage per game (FG%), free throw attempts per game (FTA), assists per game (AST), steals per game (ST), turnovers per game (TO) and blocks per game (BLK).

Statistical Analyses

The data analysed within the scope of the research were obtained from the Euroleague’s official statistics website (www.euroleague.net). Shapiro-Wilk test was applied to check the normality of data and normal distribution has found. Home game statistics of successful and unsuccessful teams were analysed with Paired Sample t-test. SPSS 22 was used in the analysis of the data. The level of significance in all analyses was accepted as $p<0.05$.

FINDINGS

This research aimed to compare the home game performances of Euroleague teams in 2018-2019 and 2020-2021 seasons. Euroleague teams played 17 home games in 2018-2019 season as they played total of 15 in 2020-2021 season.

Table 1. Teams with most home wins and most home loses in 2018-2019 season

	Team	W	L	PTS	2PT%	3PT%	FGM	FGA	FG%	FTA	AST	ST	TO	BLK
SUCCESSFUL	FC Bayern Munich	13	4	79,2	,49	,40	28,5	61,7	,46	17,4	16,7	8,4	12	2,2
	FC Barcelona	12	5	81,8	,54	,43	29,4	59	,50	18,4	18,2	7,1	14,5	2,7
	Valencia Basket	12	5	82,2	,57	,35	29,5	60,6	,49	18,2	20,2	6,8	13,2	2
	CSKA Moscow	12	5	83,6	,54	,39	30,1	62,5	,49	18,1	15,4	5,7	11,5	2,1
	Anadolu Efes İstanbul	11	6	80,6	,58	,36	29	60,3	,48	16,2	18,1	7	11,9	2,4
UNSUCCESSFUL	Panathinaikos OPAP Athens	8	9	82,8	,54	,38	29,6	62,4	,47	18,9	18	6,6	12,5	3,2
	Olympiacos Piraeus	7	10	78,1	,57	,35	28	59,5	,47	17,8	17,8	7,5	13,3	2,1
	Crvena Zvezda mts Belgrade	6	11	75,8	,48	,38	26,1	59,1	,44	17,6	15,2	7	12,6	1,6
	ALBA Berlin	6	11	76,6	,51	,35	28,4	64,4	,44	11,9	20,5	7,4	14,0	1,7
	Khimki Moscow Region	3	14	79,7	,50	,36	27,7	63,5	,44	16,9	18,8	7	12,7	3,7

Per-home game statistics of the successful and unsuccessful teams in 2018-2019 season are presented in Table 1. FC Bayern Munich was the team with the most wins at home (13 wins), while Khimki Moscow Region was the most unsuccessful home team (14 loses) in 2018-2019 Euroleague season.

Table 2. Teams with most home wins and most home loses in 2020-2021 season

	Team	W	L	PTS	2PT%	3PT%	FGM	FGA	FG%	FTA	AST	ST	TO	BLK
SUCCESSFUL	Fenerbahçe İstanbul	15	0	85,9	,61	,43	31,2	57,6	,54	17,4	19,1	7,0	11,3	2,3
	CSKA Moscow	13	2	86,8	,50	,42	29,2	62,2	,47	24,6	16,3	5,8	11,8	1,8
	Real Madrid	13	2	91,9	,60	,38	33,1	64,4	,52	19	21,6	5,2	10,4	3,1
	Anadolu Efes İstanbul	12	3	87,6	,60	,42	32,8	62,1	,53	14	20,8	6,6	11,6	3,1
	FC Barcelona Lassa	12	3	80,4	,55	,38	29,1	59,6	,49	18,8	17,6	6,6	13,4	3
UNSUCCESSFUL	Zalgiris Kaunas	8	7	81,8	,55	,41	28,8	55,9	,52	21,9	19	5,6	13,4	1,5
	Buducnost Voli Podgorica	6	9	75,8	,49	,41	27,9	60,8	,46	15	15,6	6,1	11,4	2,6
	Herbalife Gran Canaria	6	9	81,6	,53	,36	28,8	62,2	,47	20,4	18,2	6,7	12,4	2,1
	Khimki Moscow Region	6	9	77,6	,54	,34	27,1	60,4	,45	17,6	18,2	7,4	11,9	3,6
	Darüşşafaka İstanbul	5	10	77,7	,51	,33	28,3	63	,45	18,5	17,8	5,8	12,4	3,8

Per-home game statistics of the successful and unsuccessful teams in 2020-2021 season are presented in Table 2. In the 2020-2021 Euroleague season, Fenerbahçe İstanbul did not lose a single game at home during the regular season (15 wins), meanwhile another Turkish team Darüşşafaka İstanbul has only won 33% of their home games (5 wins).

Table 3. Comparison of successful teams' home game statistics in 2018-2019 and 2020-2021 seasons

	Mean	**Std. D.**	**df**	**t**	**p**
Wins	1,000	,707	4	3,162	**,034***
Loses	-3,000	,707	4	-9,487	**,001***
Points	5,018	3,617	4	3,103	**,036***
2PT%	,028	,066	4	,947	,397
3PT%	,020	,017	4	2,582	,061
FGM	1,768	1,717	4	2,302	,083
FGA	,346	3,233	4	,239	,823
FG%	,026	,040	4	1,440	,223
FTA	1,214	3,773	4	,719	,512
AST	1,380	2,820	4	1,094	,335
ST	-,766	1,061	4	-1,615	,182
TO	-,934	1,866	4	-1,119	,326
BLK	,376	,826	4	1,017	,367

Table 3 contains the changes in the per-game statistics of the successful home teams in the 2018-2019 and 2020-2021 seasons. Analyses have shown that, in 2020-2021 Euroleague season, successful teams won less game ($p<0,05$). and scored less points per game at home compared to the pre-COVID-19 pandemic ($p<0,05$). Also, successful home teams lost more games at home in the season played after the COVID-19 outbreak ($p<0,01$).

Table 4. Comparison of unsuccessful teams' home game statistics in 2018-2019 and 2020-2021 seasons

	Mean	**Std. D.**	**df**	**t**	**p**
Wins	,200	1,095	4	,408	,704
Loses	-2,200	1,095	4	-4,491	**,011***
Points	,274	3,333	4	,184	,863
2PT%	,004	,050	4	,180	,866
3PT%	-,914	1,708	4	-1,197	,298
FGM	,006	,038	4	,355	,741
FGA	,202	1,563	4	,289	,787
FG%	-1,342	3,891	4	-,771	,484
FTA	,018	,023	4	1,765	,152
AST	2,036	3,140	4	1,450	,221
ST	-,328	2,314	4	-,317	,767
TO	-,786	,610	4	-2,883	**,045***
BLK	-,762	1,249	4	-1,364	,244

Changes in the per-game statistics of the unsuccessful home teams in the 2018-2019 and 2020-2021 seasons are presented in Table 4. Unsuccessful teams lost more games at home in 2020-2021 season compared to 2018-2019 ($p<0,05$). Also, there was a significant increase in turnovers per game, which means less possession for the teams in offense ($p<0,05$).

DISCUSSION

This research aimed to compare home performance in the Euroleague in the pre- and post-COVID-19 seasons. Home statistics of Euroleague teams in 2018-2019 and 2020-2021 seasons were compared. Changes in home court performances were compared by analysing the home statistics of Euroleague teams in the 2018-2019 and 2020-2021 seasons.

Home advantage in basketball is an often researched and commented topic. Home teams can increase their chances of winning by taking advantage of the conditions such as the crowd support, familiar playing environment and the travel of the opposing team. In a study investigating home advantage, Courneya and Carron (5) stated that basketball teams won 64.4% of home games. The COVID-19 pandemic has greatly affected all sports organizations. While some organizations were suspended, some were cancelled, while others were restarted by creating neutral conditions. The 2019-2020 season in the Euroleague could not be completed due to the COVID-19 outbreak. In the new season, all games were played without spectators.

In our research, it was concluded that the successful home teams in the Euroleague won fewer games than the season before the COVID-19 outbreak. However, successful teams have lost more games at home. Researchers think that the decrease in the number of wins is due to the lack of support from the spectators of the home teams. On the other hand, Leota et al. (1994) stated that the chances of the home teams to win the game increase in the games played with the support of the audience in the NBA. Leota, et al. (14) noted that in gems played with spectators, the probability of winning the home team increased by 15.91%. Kotecki (12) also stated that FG%, FT%, and points scored by home team increased in teams' home games.

The 2020 NBA playoffs were played on an isolated campus, with no travel and no spectators. In this environment, it was seen that the so-called home teams lost 12% more matches in the home field (20). It is thought that this is due to away teams not traveling, not encountering spectator pressure and not playing in unfamiliar venues. Stefani (25) emphasized that the home advantage in the playoffs is stronger than the games played in the regular season. Another finding of our research is that the home teams scored less in the games played without spectators. van Bommel, et al. (29) stated that all game related statistics of NCAA basketball teams increased in home games. Researchers have noted that the audience has an influence on the decision of the referees in favour of the home team. Referees may want to appease the spectators and respond to the noise and reactions of the spectators in favour of the home team (6).

The results of our research show that the number of losses of the unsuccessful teams increased in the season when the games were played without spectators. Studies have emphasized that the number of spectators and spectator support are important for teams. On the other hand, others reported that the intensity of spectator support rather than the number of spectators determines the home advantage. Another result is that unsuccessful teams make more turnovers in matches without spectators. Previous studies (8, 30) stated that spectator support affects the efforts of the teams and increases the number of rebounds. It can be thought that the presence of the audience increases the game concentration of the teams.

CONCLUSION

Home court performance is one of the important factors affecting the season-long success of the teams in basketball, especially in the Euroleague. In this research, the performances of the home teams were compared in the games played with and without spectators, taking advantage of the observation opportunity created by the COVID-19 pandemic.

Home advantage depends on many factors, notably fan support, travel and familiarity. However, the absence of spectator support and away teams’ reduced travel fatigue reduces the advantage of the home teams. Therefore, this research states fan support as an important determinant of home game performance for successful or unsuccessful teams in Euroleague basketball. Future research may focus on different variables of the game to explain the home advantage.

ACKNOWLEDGMENTS

Competing Interests: The authors have no relevant financial or non-financial interests to disclose.

Funding: The authors received no financial support for the research, authorship, and/or publication of this article.

Author contributions: Research concept and study design: TD, MG; literature review: TD; data collection: TD, MG; data analysis and interpretation: TD, MG; statistical analyses: TD; writing of the manuscript: TD, MG.

REFERENCES

1. Agnew GA and Carron AV. Crowd effects and the home advantage. International Journal of Sport Psychology, 1994.
2. Alexandros L, Panagiotis K, and Miltiades K. The existence of home advantage in volleyball. International Journal of Performance Analysis in Sport 12: 272-281, 2012.
3. Clarke SR and Norman JM. Home ground advantage of individual clubs in English soccer. Journal of the Royal Statistical Society: Series D (The Statistician) 44: 509-521, 1995.
4. Coste O, Van Beers P, and Touitou Y. Hypoxia-induced changes in recovery sleep, core body temperature, urinary 6-sulphatoxymelatonin and free cortisol after a simulated long-duration flight. Journal of sleep research 18: 454-465, 2009.
5. Courneya KS and Carron AV. The home advantage in sport competitions: a literature review. Journal of Sport & Exercise Psychology 14, 1992.
6. Downward P and Jones M. Effects of crowd size on referee decisions: Analysis of the FA Cup. Journal of sports sciences 25: 1541-1545, 2007.
7. Entine OA and Small DS. The role of rest in the NBA home-court advantage. Journal of Quantitative Analysis in Sports 4, 2008.
8. Goldman M and Rao JM. Effort vs. concentration: the asymmetric impact of pressure on NBA performance. Presented at Proceedings of the MIT Sloan sports analytics conference, 2012.
9. Harville DA and Smith MH. The home-court advantage: How large is it, and does it vary from team to team? The American Statistician 48: 22-28, 1994.
10. Jones MB. Home advantage in the NBA as a game-long process. Journal of Quantitative Analysis in Sports 3, 2007.
11. Jones MB. The home advantage in major league baseball. Perceptual and motor skills 121: 791-804, 2015.
12. Kotecki J. Estimating the effect of home court advantage on wins in the NBA. Illinois Wesleyan University, 2014.
13. Leatherwood WE and Dragoo JL. Effect of airline travel on performance: a review of the literature. British journal of sports medicine 47: 561-567, 2013.
14. Leota J, Hoffman D, Mascaro L, Czeisler MÉ, Nash K, Drummond S, Anderson C, Rajaratnam SM, and Facer-Childs E. Home is where the hustle is: The influence of crowds on effort and home advantage in the National Basketball Association. Available at SSRN 3898283, 2021.
15. Nédélec M, McCall A, Carling C, Legall F, Berthoin S, and Dupont G. Recovery in soccer. Sports medicine 43: 9-22, 2013.
16. Nevill AM, Newell SM, and Gale S. Factors associated with home advantage in English and Scottish soccer matches. Journal of sports sciences 14: 181-186, 1996.
17. Palao JM, García-de-Alcaraz A, and Valadés D. Home Advantage in Volleyball, in: Home Advantage in Sport. Routledge, 2021, pp 243-250.
18. Pollard R and Gómez MA. Comparison of home advantage in men's and women's football leagues in Europe. European journal of sport science 14: S77-S83, 2014.

19. Price J, Remer M, and Stone DF. Subperfect game: Profitable biases of NBA referees. Journal of Economics & Management Strategy 21: 271-300, 2012.
20. Price M and Yan J. The Effects of the NBA COVID Bubble on the NBA Playoffs: A Case Study for Home-Court Advantage. arXiv preprint arXiv:210302832, 2021.
21. Quinn KG, Bursik PB, Borick CP, and Raethz L. Do new digs mean more wins? The relationship between a new venue and a professional sports team's competitive success. Journal of Sports Economics 4: 167-182, 2003.
22. Randall Smith D. Disconnects between popular discourse and home advantage research: What can fans and media tell us about the home advantage phenomenon? Journal of Sports Sciences 23: 351-364, 2005.
23. Reilly T. Ergonomics in sport and physical activity. Human Kinetics, 2009.
24. Schwartz B and Barsky SF. The home advantage. Social forces 55: 641-661, 1977.
25. Stefani R. Measurement and interpretation of home advantage. Statistical thinking in sports: 203-216, 2008.
26. Sutter M and Kocher MG. Favoritism of agents–the case of referees' home bias. Journal of Economic Psychology 25: 461-469, 2004.
27. Thout SM, Kavouras SA, and Kenefick RW. Effect of perceived ability, game location, and state anxiety on basketball performance. Journal of Sport Behavior 21: 311, 1998.
28. Turnbull LI. Home Sweet Home: A Statistical Analysis of Home Court Advantage in Division I College Basketball. 2021.
29. van Bommel M, Bornn L, Chow-White P, and Gao C. Home sweet home: Quantifying home court advantages for NCAA basketball statistics. Journal of Sports Analytics 7: 25-36, 2021.
30. White MH and Sheldon KM. The contract year syndrome in the NBA and MLB: A classic undermining pattern. Motivation and Emotion 38: 196-205, 2014.
31. Wunderlich F, Weigelt M, Rein R, and Memmert D. How does spectator presence affect football? Home advantage remains in European top-class football matches played without spectators during the COVID-19 pandemic. Plos one 16: e0248590, 2021.
32. Yi DT. The Home Court Advantage: Evidence from Men's College Basketball. Sport Journal, 2017.

Performance Analysis in Sport and Exercise

Ankara University Performance Analysis in Sports Application and Research Center

Available online 5 December 2022

Does the Tibialis Flexion Exercise Affects Sprint Performance in Youth Soccer Players?

Aysberg Şamil Önlü [1*], Mete Berk Demiryol [2], Erdem Çakan [1]
[1] Faculty of Sport Sciences, Ankara University, Ankara, Turkey
[2] Faculty of Sport Sciences, İnönü University, Malatya, Turkey

Abstract

This study investigated the effects of tibialis flexion exercise on sprint performance in young soccer players. 15 young male soccer players (age: 16.53 ± 1.36 years, height: 180.60 ± 4.36 cm, body weight: 69.80 ± 6.28 kg) playing soccer in the U-17 age category of a professional soccer team voluntarily participated in the study. Before the team soccer training, tibialis flexion exercise was performed 3 times a week. This process continued for 4 weeks. Due to the progressive loading method, 5 repetitions were added to the movement repetition after a training week ended. After the last practice of the week, a 30-meter sprint test was conducted. The test was measured using the "MySprint" application. Every 5-meter piece of the run was compared. As a result of the study, a significant difference in the test results of the last two weeks in terms of duration was observed in different parts of the 30-meter run.

Key Words: Sprint, anterior tibialis, tibialis flexion, soccer

INTRODUCTION

According to the researches, the distances covered by elite soccer players in matches vary between 9-14km (6, 11). In addition, over the distance coverage, players take between 150-250 different types of action. The actions taken depends on the players physical characteristics and the roles in the game (5). Apart from this, relationship between distance coverage with winning the game, creating a position or scoring a goal is quite superficial and it is not possible to being discussed about how the coverage is affecting these aspects (34). The sprint activity is one of the important aspect in soccer, the distance covered with sprints is limited between 1% to 12% total, which corresponds 0.5% to 3% of the playing time (40). Moreover soccer players perform between 3 to 40 sprint activity per game. These numbers may based on the player’s position on the field and it has rarely been seen that the distances covered with the sprint activity exceed 20 meters, or 4 seconds in duration (1). Thus, when if it does not separated according to their positions on the field, average distance covered by 147 soccer players with the sprint activity is 237 + 124 meters and the soccer players speed is more than 24km/h while they travel these distances (6).

Start with to win a soccer match, one team must score more goals than the other team without disqualification. Regardless of soccer player's position, a player playing in the field can score. Besides, the most important players to score goals are the attacking player and the best attacking players are the ones who can score goals (43). In terms of scoring goals being the most important factor in conditions of being winner of the game, how the score is produced has been investigated on a broader spectrum. Accordingly, goals occurred after high intensity activities or high intensity activity was observed at least once in the development of the produced goals. In a sample study, 298 of the 360 goals (83%) scored in the German National League showed at least one high intensity activity performed by the player who scored or gave the pass to the scorer. Thus, the high intensity activity that stands out in those goals or assists is the sprint activity which is dominant activity for scoring (15). According to the same research, the goals scored was formed after the attacking player's high intensity run (sprint) without dribbling the ball (dummy run). The truth of a previous assertion may be confirmed or contradicted by, in the researches, athletes with high sprint speeds can pass the defenders more easily, their scoring percentages are higher, they create more effective shooting positions and the percentage of goalkeepers to save these shoots are less likely (41,42). Likewise, it was observed that the games won in the German National League, attacking and midfielders covered a higher number of sprint distances than in the games lost (2). It can be said that sprint activity is important in soccer and can increase the success rate when its improved. Managers and athletic performance coaches use training methods which improves sprint ability, both before and during their season. But, in a sport such as soccer, it is difficult to implement these methods and versatile training plans for various reasons. Firstly, soccer is a team game and that a high amount of time for training should be allocated to technical and tactical training. Therefore, the technical team and coaches would spend more time on tactical training instead of doing any extra physical work if there are no major deficiencies. In addition to that, considering the travel time and rest requirements of the soccer players, it is difficult to do extra physical training during the season (25).

Sprint is called the running of people with unaided movements with maximal exertion (22). Sprint ability can be improved with various methods. These are; improving and correcting of running technique, strengthening the muscles of the lower extremities, making the lower extremity muscles more durable, fitness applications that can be applied for power generation and basically sprinting more often (3,8,24,31,37). According to the studies, the muscles of the lower extremities affect the different phases of the sprint in different ways. Knee flexors and plantar flexor are significantly important factors in the first 15 meters of a 40 meter sprint run (10). Also, knee extensors, plantar flexors and hip extensors are effective in the power generation of 35 meters of sprint activity (15). Conforming to the literature review and the studies observed, technical-tactical training in soccer has been given priority and development of the physiological aspects of the players is put on the second plan, especially during the season. The reason behind this situation is in order to use the time economically because the trainings which can improve the physiological aspects can take long process and the adaptation would take a long time. (13, 23). These reasons and situations shows that there is a need for new methods which have valid that can be implemented for improve physiological aspects of soccer players during the season. Researches shows, improvements on knee extensors, knee flexors and hip muscles positively affects sprint performance (7, 9, 35). However, there is no scientific research shows that development of tibialis anterior which is a lower extremity muscle, can increase sprint performance. It is known that the tibialis anterior muscle appears to be more active than other muscles during certain phases of running (30, 33). The aim of this study is to find out whether exercise performed to improve tibialis anterior muscles affects sprint performance in young soccer players.

METHODS

Study Design

The study consisted of 4 weeks starting from the first test to the last test as a total of 5 tests and 12 exercises (Table 1). The training was held 3 days a week in the facilities where the club trained. After the height and body weight measurements were taken from the participants on the first day of the first week, a 30-meter sprint test was applied and then they were allowed to do their first training after taking enough breaks to rest. Then, each subsequent week, a 30-meter sprint test was performed before the third training day (Table 1). All the practices were performed in the first part of the workout. Apart from the practices, the athletes continued their routine training. The researchers progressively increased their exercise repeat count each week throughout the training protocol. After the training, passive stretching exercise was applied to reduce the risk of injury of the participants. For the last measurement only, it was ensured that 48 hours had passed since the last training time.

Table 1. Table showing the days that the subjects will participate in the study and in which studies the measurements were taken.

Week 1	Week 2	Week 3	Week 4
Day 1 – Body height and weight, 30m Sprint measurements and first training	Day 1– training	Day 1– training	Day 1– training
Day 3– training	Day 3– training	Day 3– training	Day 3– training
Day 5– 30m Sprint measurement and training	Day 5– 30m Sprint measurement and training	Day 5– 30m Sprint measurement and training	Day 5– training
Day 6 - rest	Day 6 - rest	Day 6 - rest	Day 6 - rest
-	-	-	Day 7 – Last 30m sprint measurements

Subjects

Fifteen male athletes (age: 16.53 ± 1.36 years, height: 180.60 ± 4.36 cm, body weight: 69.80 ± 6.28 kg) playing in the U-17 age category of a professional soccer team voluntarily participated in the study. Since the participants were under the age of 18, parental consent was also obtained. The study included athletes who had not experienced a serious injury in the past year. It was explained that the participants should not apply any extra resistance exercises other than their own routine training throughout the study. The working group did not include goalkeepers. Each participant continued their routine training throughout the study but were asked not to train strenuously and not to use beverages such as caffeine and alcohol 24 hours before the study and test days. Any positive and negative situations that may arise during the study are explained to the participants, their families and coaches.

Procedures

Athletes have practiced a warm-up procedure that they routinely practice, which includes low intensity running, specific soccer practices that are not strenuous and dynamic stretches. Then they performed the tibialis raise exercise. After all sets of exercise were completed, the athletes performed two sets of static calf raise exercise for 30 seconds to cool down.

Tibialis raise exercise is an exercise performed by performing ankle dorsiflexion. Participants lean their backs to a place where they can get support and position their feet about a step and a half forward. Before athletes begin exercise, make sure that part of their back, waist, and hips touch the place where they receive support. When athletes are in this position, they statically fix their knees at the maximum extension angle and perform dorsiflexion with their ankles. They waited 1 second at the maximum dorsiflexion angle and 1 second when the sole of their feet pressed the ground again.

When all the sets of exercise were finished, calf raise exercise was applied as a cooling exercise to prevent injury to the tibialis anterior muscle. Calf raise can also be considered as a resistance exercise, but here it is treated as a stretching exercise due to the extension of the tibialis anterior muscle. While performing the calf raise exercise, the athletes waited for 30 seconds by rising to the tips of their toes and rested for the following 1 minute. In this way, they applied a total of 2 sets and the training part of the experiment was completed.

In the tibialis raise exercise, the progressive overload method was applied to ensure that the development continued, so the number of repetitions was increased by a certain amount every week. In the first week, the exercise was practiced in 3 sets of 15 repetitions and 5 repetitions were added to the number of repetitions each week. Therefore, in the last training, the participants performed the exercise 3 sets and 30 repetitions. Due to the fact that the gastrocnemius muscle works statically while flexing the tibialis anterior muscle, no change has been made in the duration of the cooling exercise and the number of sets in order to limit the predicted development.

Table 2. Table of exercise set and repetition counts.

	Week 1	**Week 2**	**Week 3**	**Week 4**
Tibialis Raise	3x15, x-1-0-1	3x20, x-1-0-1	3x25, x-1-0-1	3x30, x-1-0-1
Calf Raise	2 x 30 seconds	2 x 30 seconds	2 x 30 seconds	2 x 30 seconds

The first of the numbers that appear in the table as 3x15 symbolizes the number of sets, and after the x, the number of repetitions.

MySprint

Mobile apps are frequently used by sports scientists and strength and conditioning coaches (16). Due to the difficulty of accessing measuring devices and economic reasons, sports scientists and coaches have started to use mobile applications (26). The increase in the use of mobile applications has led to the questioning of the reliability of the applications. The "MySprint" application we use has been evaluated by some studies in terms of reliability. When the evaluation results were examined, near-perfect correlation values were recorded between the use of photocells and the MySprint application. As a result of the systematic evaluation of the study, the MySprint mobile application was evaluated as a valid and reliable application for motion speed measurement, motion time evaluation and power output measurement (38).

The 30 meter running tests were recorded and analyzed with the "MySprint" application. The procedure in the mobile application was followed for the recording of the 30-meter test. For the measurement, 6 markings (long training sticks) that can be easily detected by the camera were used. These signs are placed in the 5-10-15-20-25 and 30 meter zones of the 30-meter running area, respectively. The camera used is located at a distance of 10 meters from the mark at 15 meters for the chest of the running athlete to record comfortably, and different distances for 5, 10, 20, 25 and 30 meters are also referenced.

The reference points on doors A (5 and 25 meters) are parallel to the camera angle (appropriate), but also 0.57 meters away from the 5 and 25 meter transition points, parallel to the camera angle for the reference points at gates B (10 and 20 meters) and 0.28 meters away from the transition points, and finally the reference points at point C are parallel to the camera angle (appropriate) and 0.85 meters away from the transition point set. In order to ensure that the participants could accelerate, the participants were asked to start 50 cm behind the starting point of the 30 meter running track. When the participants were ready, they started the test.

Statistical Analysis

After the measurements were taken, the data were processed with the “SPSS 22” program. First of all, the normality analysis of the data was made. Since the data were homogeneously and normally distributed, the "One Way ANOVA" test was applied and analyzed at 95% confidence interval. The evaluation between each examined data was made according to Post-Hoc. It has also been interpreted according to Scheffe, Bonferroni, Tukey.

FINDINGS

In this study, it was observed that the participants had a decrease in their 30 meter sprint time as a result of 4 weeks of training and one test every week (every 3 exercises were over). According to the results obtained, it was observed that the duration of the participants did not change between the 1st week, the 2nd week and the 3rd week in the 5 meter sprint duration. Likewise, it was determined that the durations of 10 meters, 15 meters, 20 meters, 25 meters, 30 meters sprint durations did not change in the 1st, 2nd and 3rd weeks. When looked at in more detail, it was observed that the exercises performed during the sprint periods of the participants in the first week produced a relative change. However, when looking at the 4th and 5th week, it is found that there is a significant change in the transition times for every 5 meters sprint distance.

Table 3. The results of the 30-meter sprint test based on the interpretations of Bonferroni, Scheffe and Tukey.

	Week 1		**Week 2**		**Week 3**		**Week 4**		**Week 5**	
	Means (sec)	**S.s. (±)**	**Means (sec)**	**S.s. (±)**	**Means (sec)**	**S.s. (±)**	**Means (sec)**	**S.s. (±)**	**Means (sec)**	**S.s. (±)**
5 meters	1.00	0.06	0.98	0.04	0.93	0.07	0.87*	0.09	0.82^{α}	0.12
10 meters	1.72	0.09	1.70	0.05	1.67	0.08	1.60*	0.09	1.54^{α}	0.12
15 meters	2.34	0.10	2.37	0.06	2.34	0.08	2.25*	0.10	2.20^{α}	0.13
20 meters	2.96	0.12	3.01	0.08	2.98	0.10	2.89*	0.11	2.80^{α}	0.14
25 meters	3.58	0.15	3.61	0.10	3.63	0.12	3.51*	0.13	3.41^{α}	0.14
30 meters	4.19	0.18	4.28	0.13	4.27	0.14	4.13*	0.15	4.05^{β}	0.16

* Significant for week 1,2,3,4 ($p < 0.05$), $^{\alpha}$ significant for week 1,2,3 ($p<0.05$), $^{\beta}$ significant for week 2,3($p<0.05$).

As a result of the analysis of the data, the findings of Bonferonni, Scheffe and Tukey based on the interpretations of the tibialis raise exercise performed on young soccer players;

- At the 5, 10, 15 and 20 meters; In the 4th week according to the 1st and 2nd week, in the 5th week according to the 1st-2nd-3rd weeks,
- At 25 meters; In the 5th week according to the 1st-2nd-3rd weeks,
- In 30 meters, a statistically significant difference was found in 5th week compared to 2nd and 3rd week.

Table 4. Results of one-way ANOVA.

	Sum of squares	**df**	**Mean Square**	**F**	**d**
5 meters	0.344	4	0.86	13.040	0.000
10 meters	0.319	4	0.80	10.428	0.000
15 meters	0.315	4	0.79	8.444	0.000
20 meters	0.432	4	0.108	8.628	0.000
25 meters	0.491	4	0.123	7.369	0.000
30 meters	0.556	4	0.139	5.926	0.000

Looking at the "One-Way ANOVA" results of the participants; There were significant differences between the participants' 5 meter transition time of the exercise performed each week ($p<0.05$). A significant difference was found between the first test observed and the last test. As a result, it was observed that the tibialis raise movement had an effect on the 30-meter sprint speed of young soccer players as a result of a 4-week program.

DISCUSSION

There are many studies in the literature related to the development and importance of sprint running in soccer. In some of these studies, we can mention the existence of studies that conclude that the development of the muscles of the lower extremities plays an important role for the development of sprinting skills (39). However, there is a lack of studies in the literature specifically considering the effect of anterior tibialis development on sprint in soccer.

Based on the information provided, the aim of the study was to investigate the effects of the tibialis raise exercise applied to soccer players on sprint performance. In line with the aim of our study, the effects of tibialis raise movement on sprint performance in soccer players were determined with the training process lasting 4 weeks and performed 3 times every week. When the results were examined, it was seen that tibialis raise exercise had significant effects on the development of sprint performance.

According to a study, 49% of the distance covered by soccer players in the sprint during the match is shorter than 10 meters and 96% is shorter than 30 meters (37). With the data we obtained from our study, we can say that our training improves the performance of the soccer players within the expected sprint distance.

In a study by, it was found that the fastest soccer players were (approximately) 0.6 seconds slower than the fastest sprinters in the world at runs over 40 meters (17). In addition, when the individual test results in the latest studies are examined, it has been determined that the fastest male soccer players can reach 40-meter sprint performances equivalent to the 60-meter run finalists at the national athletics championships. The 1 on 1 situation in soccer requires being faster than the opponent or eliminating the opponent. He said that about 30 to 50 cm is enough to rule out the opponent with the body or shoulder in 1-on-1 situations in soccer. The meaningful results we have achieved in our work play an important role in these critical situations and characteristics related to sprinting in soccer.

Running consists of cycles and certain phases of cycles. For the running skill to be realized correctly, all the elements of these cycles must work in synchronization. With the end of the support phase (stance) of the run, the plantar flexors cease their activity and the tibialis anterior activity for foot dorsiflexion begins (36). During the flight phase of running, the rectus femoris and tibialis anterior are highly active muscles (27). In the data determined as a result of the study, the duration of the 30 meter run in the fourth and fifth week of the training was determined in the 5-10-15-20 meter phases. While the average duration of the 5th week of 5 meters was 0.82, the durations of the 1st, 2nd and 3rd weeks were recorded as 1.0-0.98 and 0.93, respectively. With these data, it can be concluded that the tibialis is related to the development of the anterior muscle.

With dorsiflexion, especially during the oscillation phase of the sprint, the anterior tibialis becomes the most active. In his study by Tom F. Novacheck (1998), he said that elite athletes used the forefoot area very actively during the sprint and thus showed their performance, and that the heel area did not even touch the ground (28). Lockie et al. (2013) also said that for the 10-meter running time to improve, there should be longer steps, longer flight time and shorter contact time (20). With the conclusion reached in our study, the tibial raise exercise a. We can say that it plays an active role in the development of tibialis and therefore in the development of sprints. However, we can state that the development of anterior tibialis will have a positive effect on the duration of release.

The tibialis anterior muscle contracts concentrically during the sprint and the foot is stabilized. In addition, it maintains speed by moving the tibia forward on the foot (21). When we compare the 25 and 30 meters data of the fifth week of our study with the 25 meters data of the first, second and third weeks, and 30 meters of the second and third weeks, we see the improved sprint time. At the end of the 4-week training period, we can say that the 30 meter runs in the first weeks improved the sprint times.

The calf raise exercise performed after the tibialis raise exercise in our study aims to prevent excessive hypertrophic development due to tibialis raise exercise by providing stretching by performing statically. On the other hand, it also causes the development of the gastrocnemius muscle. In a study by Prilutsky and Zatsiorsky (1994), it was said that the rectus femoris and gastrocnemius muscles help to extend the joints by carrying mechanical energy to the distal joints (32). Based on this, it can be said that the calf raise exercise we do has an effect on the sprinting skills of our participants.

REFERENCES

1. Andrzejewski, M., Chmura, J., Pluta, B., & Konarski, J. M. (2015). Sprinting activities and distance covered by top level Europa league soccer players. *International Journal of Sports Science & Coaching*, *10*(1), 39-50.
2. Andrzejewski, M., Chmura, P., Konefał, M., Kowalczuk, E., & Chmura, J. (2018). Match outcome and sprinting activities in match play by elite German soccer players. *The Journal of sports medicine and physical fitness*, *58*(6), 785-792.
3. Asadi, A., Ramirez-Campillo, R., Arazi, H., & Sáez de Villarreal, E. (2018). The effects of maturation on jumping ability and sprint adaptations to plyometric training in youth soccer players. *Journal of sports sciences*, *36*(21), 2405-2411.
4. Bangsbo, J. (1994). The physiology of soccer: With special reference to intense intermittent exercise. Acta Physiologica Scandinavica, 619, 151.
5. Bangsbo, J., Mohr, M., & Krustrup, P. (2006). Physical and metabolic demands of training and match-play in the elite football player. Journal of sports sciences, 24(07), 665-674.
6. Barros, R. M. L., Misuta, M. S., Menezes, R. P., Figueroa, P. J., Moura, F. A., Cunha, S. A., et al. (2007). Analysis of the distances covered by first division Brazilian soccer players obtained with an automatic tracking method. Journal of Science and Medicine in Sport, 6, 233242
7. Bautista, I. J., Vicente-Mampel, J., Baraja-Vegas, L., Segarra, V., Martín, F., & Van Hooren, B. (2021). The effects of the Nordic hamstring exercise on sprint performance and eccentric knee flexor strength: A systematic review and meta-analysis of intervention studies among team sport players. *Journal of Science and Medicine in Sport*, *24*(9), 931-938.
8. Buchheit, M., Mendez-Villanueva, A., Delhomel, G., Brughelli, M., & Ahmaidi, S. (2010). Improving repeated sprint ability in young elite soccer players: repeated shuttle sprints vs. explosive strength training. *The Journal of Strength & Conditioning Research*, *24*(10), 2715-2722.
9. Deane, R. S., Chow, J. W., Tillman, M. D., & Fournier, K. A. (2005). Effects of hip flexor training on sprint, shuttle run, and vertical jump performance. *The Journal of Strength & Conditioning Research*, *19*(3), 615-621.
10. Delecluse, C. (1997). Influence of strength training on sprint running performance. Current ˆndings and implications for training. Sports Med., 24(3): 147-156
11. Di Salvo, V., Baron, R., Tschan, H., Calderon Montero, F. J., Bachl, N., & Pigozzi, F. (2007). Performance characteristics according to playing position in elite soccer. International Journal of Sports Medicine, 28, 222227.
12. Di Salvo, V., Benito, P. J., Calderon Montero, F. J., Di Salvo, M., & Pigozzi, F. (2008). Activity profile of elite goalkeepers during football match-play. Journal of Sports Medicine and Physical Fitness, 48, 443446.
13. Djaoui, L., Haddad, M., Chamari, K., & Dellal, A. (2017). Monitoring training load and fatigue in soccer players with physiological markers. *Physiology & behavior*, *181*, 86-94.
14. D. Johnson, M., & Buckley, J. G. (2001). Muscle power patterns in the mid-acceleration phase of sprinting. Journal of sports sciences, 19(4), 263-272.
15. Faude, O., Koch, T., & Meyer, T. (2012). Straight sprinting is the most frequent action in goal situations in professional football. *Journal of sports sciences*, *30*(7), 625-631.

16. Ferriero, G., Vercelli, S., Fundarò, C., & Ronconi, G. (2020). Use of mobile applications to collect data in sport, health, and exercise science: A narrative review. *The Journal of Strength & Conditioning Research*, *34*(12), e276.
17. Haugen, T. A., Tønnessen, E., Hisdal, J., & Seiler, S. (2014). The role and development of sprinting speed in soccer. *International journal of sports physiology and performance*, *9*(3), 432-441.
18. Johnson, M. D., and Buckley, J. G. (2001). Muscle power patterns in the mid-acceleration phase of sprinting. J. Sports Sci., 19(4): 263-272
19. Lago, C., & Martin, R. (2007). Determinants of possession of the ball in soccer. Journal of Sports Sciences, 25, 969974
20. Lockie, R. G., Murphy, A. J., Jeffriess, M. D., & Callaghan, S. J. (2013). STEP KINEMATIC PREDICTORS OF SHORT SPRINT PERFORMANCE IN FIELD SPORT ATHLETES. *Serbian Journal of Sports Sciences*, *7*(2).
21. Mann, R. A., & Hagy, J. (1980). Biomechanics of walking, running, and sprinting. *The American journal of sports medicine*, *8*(5), 345-350.
22. Mann, R., & Sprague, P. (1983). Kinetics of sprinting. In ISBS-Conference Proceedings Archive.
23. Mcmillan, K., Helgerud, J., Macdonald, R., & Hoff, J. (2005). Physiological adaptations to soccer specific endurance training in professional youth soccer players. *British journal of sports medicine*, *39*(5), 273-277.
24. Mendiguchia, J., Martinez-Ruiz, E., Morin, J. B., Samozino, P., Edouard, P., Alcaraz, P. E., ... & Mendez-Villanueva, A. (2015). Effects of hamstring-emphasized neuromuscular training on strength and sprinting mechanics in football players. *Scandinavian journal of medicine & science in sports*, *25*(6), e621-e629.
25. Morgans, R., Orme, P., Anderson, L., & Drust, B. (2014). Principles and practices of training for soccer. *Journal of Sport and Health Science*, *3*(4), 251-257.
26. Muntaner-Mas, A., Martinez-Nicolas, A., Lavie, C. J., Blair, S. N., Ross, R., Arena, R., & Ortega, F. B. (2019). A systematic review of fitness apps and their potential clinical and sports utility for objective and remote assessment of cardiorespiratory fitness. *Sports Medicine*, *49*(4), 587-600.
27. Nicola, T. L., & Jewison, D. J. (2012). The anatomy and biomechanics of running. *Clinics in sports medicine*, *31*(2), 187-201.
28. Novacheck, T. F. (1998). The biomechanics of running. *Gait & posture*, *7*(1), 77-95.
29. Ounpuu, S. (1994). The biomechanics of walking and running. *Clinics in sports medicine*, *13*(4), 843-863.
30. O'Connor, K. M., & Hamill, J. (2004). The role of selected extrinsic foot muscles during running. *Clinical biomechanics*, *19*(1), 71-77.
31. Petrakos, G., Morin, J. B., & Egan, B. (2016). Resisted sled sprint training to improve sprint performance: a systematic review. Sports medicine, 46(3), 381-400.
32. Prilutsky, B. I., & Zatsiorsky, V. M. (1994). Tendon action of two-joint muscles: transfer of mechanical energy between joints during jumping, landing, and running. *Journal of biomechanics*, *27*(1), 25-34.
33. Reber, L., Perry, J., & Pink, M. (1993). Muscular control of the ankle in running. *The American journal of sports medicine*, *21*(6), 805-810.
34. Rienzi, E, Drust, B, Reilly, T, Carter, JE, and Martin, A. Investigation of anthropometric and work-rate profiles of elite South American international players. J Sports Med Phys Fitness 40: 162–169, 2000.

35. Seitz, L. B., Reyes, A., Tran, T. T., de Villarreal, E. S., & Haff, G. G. (2014). Increases in lower-body strength transfer positively to sprint performance: a systematic review with meta-analysis. *Sports medicine*, *44*(12), 1693-1702.
36. SEVER, O., CİĞERCİ, A. E., Rıdvan, K. I. R., BAYKAL, C., KİSHALI, N., İPEKOĞLU, G., & YAMAN, M. (2021). Koşu Biyomekaniği. *Spor Eğitim Dergisi*, *5*(1), 71-96.
37. Shalfawi, S. A., Ingebrigtsen, J., Dillern, T., Tønnessen, E., Delp, T. K., & Enoksen, E. (2012). The effect of 40 m repeated sprint training on physical performance in young elite male soccer players.
38. Silva, R., Rico-González, M., Lima, R., Akyildiz, Z., Pino-Ortega, J., & Clemente, F. M. (2021). Validity and reliability of mobile applications for assessing strength, power, velocity, and change-of-direction: A systematic review. *Sensors*, *21*(8), 2623.
39. Struzik, A., Konieczny, G., Stawarz, M., Grzesik, K., Winiarski, S., & Rokita, A. (2016). Relationship between lower limb angular kinematic variables and the effectiveness of sprinting during the acceleration phase. *Applied bionics and biomechanics*, *2016*.
40. Van Gool, D., Van Gerven, D., & Boutmans, J. (1988). The physiological load imposed on soccer players during real match-play. Science and football, 1, 51-59.
41. Wilson, R. S., Smith, N. M., Melo de Souza, N., & Moura, F. A. (2020). Dribbling speed predicts goal-scoring success in a soccer training game. *Scandinavian Journal of Medicine & Science in Sports*, *30*(11), 2070-2077.
42. Wilson, R. S., Smith, N. M., Ramos, S. D. P., Giuliano Caetano, F., Aparecido Rinaldo, M., Santiago, P. R. P., ... & Moura, F. A. (2019). Dribbling speed along curved paths predicts attacking performance in match-realistic one vs. one soccer games. *Journal of Sports Sciences*, *37*(9), 1072-1079.
43. Wilson, R. S., Smith, N. M., Santiago, P. R. P., Camata, T., Ramos, S. D. P., Caetano, F. G., ... & Moura, F. A. (2018). Predicting the defensive performance of individual players in one vs. one soccer games. *PloS one*, *13*(12), e0209822.

Performance Analysis in Sport and Exercise

Ankara University Performance Analysis in Sports Application and Research Center

Available online 5 December 2022

The Changes on HRV after a Wingate Anaerobic Test in Physically Active Adults

Veli Gül [1*]
[1] Independent Researcher

Abstract

The aim of the present study was to investigate the changes on heart rate variability (HRV) right after a Wingate Anaerobic Test (WAnT) in physically active men. The subjects performed a single 30-sec. WAnT. Their alactacid and lactacid relative power values were recorded. They participated a five-minute HRV test right before and after the WAnT. The time- and frequency-domain parameters of HRV were recorded and compared. According to the results all HRV parameters including the time- and frequency-domain parameters were significantly changed after the anaerobic loading (for HR, SDNN, SDSD, RMSSD, TP, LF, LF:HF ratio, and VLF $p<0.01$; and for HF $p<0.05$). It could be concluded that the time- and frequency-domain parameters of HRV are impaired after a supramaximal anaerobic loading. The future studies can examine the recovery process by measuring the HRV during for a long period of time after the loading.

Key Words: Anaerobic power, heart rate variability, wingate anaerobic power test

INTRODUCTION

Heart rate variability (HRV), which is a non-invasive indicator of autonomic heart functions (13) and is defined as the temporal variation between heart beats (14), is used in the field of exercise and sports sciences to determine the chronic effects of loading (10). In recent years, HRV has also been used as a measurement method to examine the effects of loading on cardiac autonomic regulation (8). In this respect, the change in the heart caused by different load types is measured and the relationship between the power values obtained and the intensity of the load can be investigated.

Anaerobic energy metabolism is energy metabolism, which is the main determinant of performance in many sports branches (3). Besides, it is also one of the skill-related elements of physical fitness, and expresses the amount of work done per unit time (15). The prerequisite for preparing a program, whether it is exercise or sports targeted, is based on the measurement of all the parameters that are desired to be developed. The Wingate anaerobic power test is also one of the most commonly used tests to determine anaerobic power (6). Unlike its counterparts, it gives information about both lactacid and alactacid power values when the standard protocol is followed and applied for 30 seconds. There are a few numbers of studies in the literature examining the relationship between HRV and short-term and intense loading. For example, in one study, the difference in HRV results measured at altitudes between 0 and about 3000 m was examined, and it was concluded that exposure to normobaric hypoxia did not have additional effects on anaerobic performance and HRV (2). In another study, HRV parameters before and after 50 m sprint swimming were examined and significant deteriorations were found in many time- and frequency-domain parameters (1).

The aim of the present study is to compare the HRV values of physically active men studying at the faculty of sports sciences before and after WAnT applied once for 30 seconds.

METHODS

Study Design

The study was carried out to examine the changes in HRV parameters of physically active men before and after a 30-second maximal anaerobic load.

Subjects

Eight physically active men who study in the faculty of sports sciences participated in the research voluntarily. The mean age of the participants was 24.25 ± 2.25 years, their height was 174.25 ± 5.09 cm, their body weight was 70.21 ± 6.94 kg, and their percent body fat was 18.70 ± 5.24%.

Procedures

The body compositions of the participants were determined with the Avis 333 plus (Korea) analyzer when the subjects were standing and wearing only shorts. Body height was measured with a Holtain brand stadiometer with a 1 mm interval (Holtain, U.K.).

Resting heart rate (HRrest) and HRV parameters were taken with an Omegawave 800 (Oregon, USA) model device. During the five-minute ECG recording, both time-domain and frequency-domain parameters of HRV were measured. The subject was placed on his back on a stretcher with only shorts on, and a total of 7 electrodes were connected to different parts of his body by applying gel. Participants were warned not to move in any way during the measurement and not to think about the subjects they would be excited about. Care was taken to ensure that the measurement room was as quiet and physically comfortable as possible. Measurements were taken twice for each person and applied as a pre- and post-test. In this study, time-domain parameters such as HR, SDNN, SDSD and RMSSD, and frequency-domain parameters such as TP, HF, LF, LF:HF ratio and VLF were recorded.

Anaerobic alactacid and lactacid strength were determined using the Wingate Test (WAnT) and the Monark Peak Bike bicycle ergometer (Varberg, Sweden). For the WAnT, a 4-minute warm-up period was applied to the participants. During the warm-up, the participants pedaled between 60-80 rpm, and at the 1.30 and 2.30 minutes, they did two sprints of 3 seconds on the ergometer without resistance. In this way, the participants were enabled to recognize the test while warming up. After warming up, passive rest was done for 5 minutes. Afterwards, the subject pedaled maximally for 30 seconds on a bicycle whose sitting height was adjusted according to his height against the weight corresponding to 7.5% of his body weight. Immediately after WAnT, subjects were taken to the second HRV measurement, so that the acute effect of the WAnT test on the heart could be examined. As a result of the test, relative peak power (PPr), average power (APr), minimum power (MPr), and power drop (PD) values were used.

During all the measurements, the laboratory temperature was kept between 20-22 °C and the humidity was kept below 60%, by using the air-conditioner. Measurements were made between 2 and 4 o'clock in the afternoon. Subjects were warned to stop eating until two hours before the measurements, not to do strenuous activities the day before, and not to consume caffeine until 12 hours before the measurements. Participants were also asked not to use drugs in the last 24 hours.

Statistical Analyses

SPSS (version 16) program was used for data analysis. The distribution of the data was first examined to determine whether parametric or non-parametric tests would be used to compare the pre- and post-test mean differences. The normality of the distribution was determined by the Shapiro-Wilk test, since the number of participants was less than 50. The pre- and post-test mean of the normally distributed data were compared with the paired sample t-test, and the pre- and post-test mean of the data without normal distribution were compared with the Wilcoxon test. The alpha value of 0.05 was accepted for all statistical analyses.

FINDINGS

The results of some of the relative values obtained from the WAnT test of the participants are shown in Table 1.

Table 1. The WAnT results.

PPr (W/kg)	11.28 ± 1.54
APr (W/kg)	8.24 ± 0.43
MPr (W/kg)	5.12 ± 0.65
PD (%)	53.77 ± 7.90

The Table 2. shows the mean values of HRV parameters before and after WAnT, and the significance of the difference between the two tests. According to the results, all time- and frequency-domain parameters changed significantly after anaerobic loading. While SDNN, SDSD, RMSSD, TP, HF, LF and VLF decreased; increases were noted in HR and LF:HF ratio.

Table 2. Comparison of HRV responses and their average values obtained before and after an anaerobic power test.

	Pre-test	**Post-test**	**p**
HR	65.75 ± 7.24	104.87 ± 13.50	0.000
SDNN	60.37 ± 20.66	16.50 ± 4.59	0.001
SDSD	68.62 ± 31.36	6.37 ± 3.11	0.001
RMSSD	53.62 ± 24.14	5.12 ± 2.69	0.001
TP	1277.62 ± 884.67	55.00 ± 28.19	0.006
LF:HF ratio	1.40 ± .95	6.78 ± 3.44	0.002
HF	599.50 ± 626.99	5.75 ± 5.47	0.012
LF	535.62 ± 292.06	31.25 ± 20.25	0.002
VLF	142.62 ± 68.61	18.00 ± 7.07	0.001

HR: Heart rate, SDNN: standard deviation of RR interval, SDSD, RMSSD: root mean square of successive differences in RR intervals, TP: total power, LF:HF: low frequency/high frequency ratio , HF: high frequency component , LF: low frequency , VLF: very low frequency components .

DISCUSSION

The aim of this study was to compare the results of HRV before and after WAnT, which is considered a supramaximal test and applied for 30 seconds in physically active men. When the results were examined, it was understood that there was a significant deterioration in all HRV parameters measured before and after loading. From the time-domain measurements of HRV, HR increased ($p<0.01$), while SDNN, SDSD and RMSSD decreased ($p<0.01$). Similar changes were seen in the frequency domain parameters. Decreases were observed in TP, LF and VLF ($p<0.01$) and HF ($p<0.05$). LF:HF ratio was recorded as high ($p<0.01$). All these changes; increasing HR, LF:HF ratio and decreasing SDNN, SDSD, RMSSD, TP, HF, LF and VLF show that the dominance of sympathetic activity increases and the effect of parasympathetic activity decreases over cardiac autonomic regulation. In addition, these changes observed in the time- and frequency-domain parameters of HRV are consistent.

In the literature, the effects of exercise or sports on HRV have been studied generally after long-term training programs. Many of the studies have investigated chronic changes. Because having HRV values below the optimal level has been associated with mortality and many diseases (4, 11, 16).

Therefore, many studies have examined whether HRV can be improved with exercise in both healthy and chronically ill groups. For example, in a study Heydari et al. (2013) reported that high-intensity interval training produced improvement in some HRV parameters of untrained men when applied for 12 weeks. Similarly, a 10-week hatha yoga program was noted to improve some HRV data of untrained healthy adults (5). Unlike these results, Monohan et al. (2000) reported that a three-month aerobic exercise program did not produce significant HRV changes in middle-aged participants. In another study, it was concluded that static streching and resistance exercises did not have an effect on HRV in postmenopausal women (7).

The number of studies examining the acute effects of an exercise application on HRV is limited in the literature. In one of these studies, changes in HRV after WAnT application in normobaric hypoxia were examined on male and female university students (2). The change in HRV parameters after WAnT at 162, 1015, 2146, and 3085 meters altitudes was investigated. According to the results, changes were observed in the HR, SDNN, SDSD, RMSSD, TP, LF:HF ratio, HF, HFnu, LF, LFnu and VLF parameters used in the study, parallel to those in the current research. All results showed that sympathetic activity increased after loading. However, no change was detected depending on altitude.

In another study, HRV changes of 13-14-year-old male swimmers were followed after 50 m freestyle sprint swimming. In this study, the swimming time was specified as 32.14 sec, and this time and the intensity of loading were similar to those in the current study. As a result, significant impairments were noted in HR, TP, LF:HF ratio, HF, HFnu, LFnu ($p<0.01$), and SDNN, SDSD, RMSSD, and LF ($p<0.05$) (1).

Tuna et al. (2020) examined changes in HRV with energy expenditure during and after one hour of hatha yoga practice. According to the results, HR was recorded significantly higher during yoga and returned to baseline at the 10th minute of recovery. Similarly, the changes observed in SDNN, RMSSD, SDSD, NN50, TRI, LF:HF ratio, HF and VLF show that practices such as yoga with long-term static contractions increase the activity of the sympathetic nervous system.

CONCLUSION

According to the results obtained from this study, it is seen that the efficiency of the sympathetic nervous system increases significantly after anaerobic loading. Accordingly, it can be said that cardiac autonomic responses are impaired after such loadings. In future studies, researchers can measure HRV until recovery after loading to examine the recovery process. In addition, measurement of lactate immediately after such a load and during the recovery period may provide additional results about the intensity of physiological overload in addition to the HRV results.

REFERENCES

1. Aras D, Akça F, Akalan C. The Effect of 50 m Sprint Swimming on Heart Rate Variability in 13-14 Year-Old Boys. SPORMETRE XI (1): 13-18, 2013.
2. Aras D, Coşkun B. The Changes on the HRV after a Wingate Anaerobic Test in Different Simulated Altitudes in Healthy, Physically-Active Adults. Acta Med Mediterr 32: 1683, 2016.
3. Bompa TO, Buzzichelli CA. Periodizaiton, Theory and Methodology of Training. Champaign, IL: Human Kinetics, 2019.
4. Borresen J, Lambert MI. Autonomic Control of Heart Rate During and after Exercise: Measurements and Implications for Monitoring Training Status. Sports Med 38 (8): 633-46, 2008.
5. Cheema BS, et al. Effect of an Office Worksite-Based Yoga Program on Heart Rate Variability: Outcomes of a Randomized Controlled Trial. BMC Complement Altern Med 13: 82, 2013.
6. Gacesa JZP, Barak OF, Grujic NG. Maximal Anaerobic Power Test in Athletes of Different Sport Disciplines. J Strength Cond Res 3 (3): 751-755, 2009.
7. Gerage AM, Forjaz CL, Nascimento MA, Januário RS, Polito MD, Cyrino ES. Cardiovascular Adaptations to Resistance Training in Elderly Postmenopausal Women. Int J Sports Med 34 (9): 806–813, 2013.
8. Gronwald T, Hoos O. Correlation properties of heart rate variability during endurance exercise: A systematic review. Ann Noninvasive Electrocardiol 25:e12697, 2020.
9. Heydari M, Boutcher YN, Boutcher SH. High-intensity Intermittent Exercise and Cardiovascular and Autonomic Function. Clin Auton Res 23: 57-65, 2013.
10. Hnidawei MA, Mjall M, Zayed Z. The upper limit of physiological cardiac hypertrophy in elite male athletes. Am J Appl Sci 7 (10): 1327-1333, 2010.
11. Lehrer PM, Vaschillo E, Vaschillo B, Lu SE, Eckberg DL, Edelberg R, Shih WJ, Lin Y, Kuusela TA, Tahvanainen KU, Hamer RM. Heart Rate Variability Biofeedback Increases Baroreflex Gain and Peak Expiratory Flow. Psychosom Med 65 (5): 796-805, 2003.
12. Monahan KD, Dinenno FA, Tanaka H, Clevenger CM, DeSouza CA, Seals DR. Regular Aerobic Exercise Modulates Age-Associated Declines in Cardiovagal Baroreflex Sensitivity in Healthy Men. J Physiol 529 (1): 263-271, 2000.
13. Myllymaki T, Rusko H, Syvaoja H, Juuti T, Kinnunen ML, Kyrolainen H. Effects of exercise intensity and duration on nocturnal heart rate variability and sleep quality. Eur J Appl Physiol 112: 801-809, 2012.
14. Pagani M et al. Power spectral analysis of heart rate and arterial pressure variabilities as a marker of sympa-tho-vagal interaction in man and conscious dog. Circ Res 59: 178-193, 1986.
15. Riebe D, Ehrman JK, Liguori G, Magal M. ACSM'S Guidelines for Exercise Testing and Prescription. Philadelphia, PA: Wolters Kluwer Health, 2018.
16. Schmidt H, et al. Autonomic Dysfunction Predicts Mortality in Patients with Multiple Organ Dysfunction Syndrome of Different Age Groups. Crit Care Med 33:1994-002, 2005.
17. Tuna ME, Aras D, Aras N, Özçelik MA, Aktop A. Acute Changes in Energy Expenditure and Heart Rate Variability during and right after One Hour of Hatha Yoga Practice. Pol J Sport Tourism 27 (4): 29-35, 2020.