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ORIGINAL RESEARCH

Subtalar joint pronation: Which is the real concern-presence or severity? A cross-sectional study

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Abstract

The study aims to compare static and dynamic postural stability, navicular drop, dorsiflexion range of motion, and jumping performance of individuals with neutral, prone, and hyperprone foot postures. Forty-eight participants between the ages of 18 and 40, were categorized into neutral (n=16), prone (n=16), and hyperprone (n=16) according to foot posture index (FPI). Static and dynamic postural control evaluations (with the Biodex Balance System SD), navicular drop test (NDT) weight-bearing lunge test, countermovement jump test without arm swing, and drop vertical jump tests have been completed. In the results, the average age of participants in the NG, PG, and HPG are 22.31 ± 2.75, 23.87± 3.72, and 22.37 ± 1.28 years and BMI are 22.6 ± 3, 23.4 ± 3.8, and 21.4 ± 2.24 (kg/m^2), respectively. The demographic data of the participants showed a homogeneous distribution. There were no significant differences in none of the outcomes except the NDT. Navicular drop amount is positively correlated by the subtalar joint pronation. An increase in subtalar joint pronation does not have a significant effect on static and dynamic stability, jump performance, or dorsiflexion range of motion in healthy individuals.

Introduction

The feet require proper weight distribution during many body motions. Pronated feet are caused by the reduced height of the medial longitudinal arch, reducing the weight distribution during static and dynamic tasks thus causing foot pain and an overall functional reduction of the lower extremities (Yoon & Park, 2013). The normal biomechanics of the foot might be disrupted due to abnormal function of the subtalar joint, namely, excessive pronation or hyperpronation. Hyperpronation is defined as rearfoot pronation that is excessive, prolonged, and, as a result, causing the foot to remain in maximum pronation, too late or never resupinate in terminal stance for push-off (Tiberio, 1998).

The feet play a role in controlling balance, thus providing stability (Hyong & Kang, 2016). Considering that the foot represents the base of support upon which the body maintains balance, it seems reasonable that even small changes in foot alignment could influence stability, movement strategies, and hence injury risk (Nilstad et al., 2014). The literature has inconsistent results in terms of study results examining the effect of pronation on static and dynamic postural stability (Cobb et al., 2004; Cobb et al., 2014; Kim et al., 2015; Hyong & Kang, 2016). Recently Bayıroğlu et al. did not find any difference between the groups in the static and dynamic evaluation performed on one leg with eyes open between prone and hyperprone foot postures, but they cited the lack of neutral groups as a limitation (Bayıroğlu et al., 2024).

The increase in subtalar joint pronation compensates for the dorsiflexion range of motion (DFROM) limitation in the ankle. As structural restriction of ankle joint dorsiflexion range limits the anterior translation of the tibia over the fixed foot during dynamic tasks, this may be compensated for by foot pronation to utilize the dorsiflexion component of subtalar and midtarsal joint motion (Jung et al., 2009). Studies are needed to examine the effect of increased pronation on DFROM, as DFROM limitations are compensated by subtalar joint pronation. To the best of our knowledge, there are not enough studies in the literature on this topic.

Functional and biomechanical comparisons of prone and neutral foot postures have been mostly investigated in the literature. The effect of the degree of pronation

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on lower extremity functionality and stability is unknown. The study aims to contribute to the literature by comparing static and dynamic postural stability, navicular drop, DFROM, and jumping performance of individuals with neutral, prone, and hyperprone foot postures. We hypothesize that individuals with hyperprone foot posture have higher navicular drop, more limited DFROM, and worse jumping performance. Still, there will be no difference in postural stability between neutral and prone foot postures.

Methods

This study was designed as a single-center, cross-sectional study to examine the effects of different subtalar joint pronation amounts on DFROM, jump performance, static and dynamic postural control. The population of the research was determined from İstanbul province of Türkiye and between the ages of 18-40. Evaluations of the participants were completed in Bahcesehir University, Physiotherapy and Rehabilitation Laboratories. The participants were categorized into prone, hyperprone, and neutral groups according to the Foot Posture Index-6 (FPI-6). Static and dynamic postural control evaluations (with Biodex Balance System SD), navicular drop test, weight-bearing lunge test (WBLT), countermovement jump (CMJ) without arm swing test, and drop vertical jump test (DVJ) have been completed. The data collection period was between 15.12.2023 and 30.04.2024. The details of the study were verbally explained to all participants, and they were informed about the possible benefits and risks of the study. After verbal declaration, a written informed consent form prepared according to the Declaration of Helsinki was given to all participants, and their consent was obtained. In addition, the study was approved by Bahcesehir University of Scientific Research and Publication Ethics Committee (E-22481095-020-343).

Participants

Thirty-eight participants aged between 18 and 40 were included in the study. According to the FPI-6, scores between 0-5 were included in the neutral group (NG) (n=16), 6-9 were included in the pronation group (PG) (n=16), and 10-12 were included in the hyperpronation group (HPG) (n=16). The sample size of our study was determined using the G*power program (v3.1.7, Germany). The sample size of the study was determined by reference to the postural stability values in the study conducted by Kouro et al. (2017). The sample size was calculated as a total of 42 participants, 14 each in the NG, PG, and HPG, with an effect size of 0.90, a margin of error of 0.05, a confidence level of 0.95, and a power of 0.90. Calculating the possibility that 20% of the participants might quit the study, a total of 48 participants were required.

Criteria for inclusion in the study require being between the ages of 18-40, not having any kind of pain and complaints, difficulty in walking, and loss of function, not undergone any surgical procedure on the lower extremity, not involved in any physical therapy program in the last 6 months, not having kind of orthopedic/neurological disease or visual and/or hearing impairment. Exclusion criteria were having a lower extremity congenital anomaly, ligament hyperlaxity, a history of tendon or cartilage injury, and a history of any shoe insert-orthosis-insoles or knee injection.

Procedure

Primary outcome

Postural stability evaluation

The postural stability evaluation protocol of Bayıroğlu et al. is adapted. The Biodex Balance System SD (Biodex Medical Systems Inc., Shirley, New York, USA) is employed to measure postural stability (PS), including both static postural stability (SPS) and dynamic postural stability (DPS). SPS is assessed with a fixed platform, while DPS is evaluated using a platform that can tilt 20° in any direction across four difficulty levels. Participants underwent a single trial test before each measurement to minimize the impact of motor learning and fatigue. Each test lasted 20 seconds and consisted of three measurements, each interspersed with 10-second rest periods. During the evaluation, participants were required to stand with their weight-bearing knees bent at 15°, their non-weight-bearing knees bent at 90°, and their arms crossed at chest height while looking straight ahead. All tests were performed with participants' eyes open and without shoes. Higher scores on the Biodex Balance System reflect a greater degree of postural instability (Bayıroğlu 2024 et al., 2024).

Secondary outcomes

Foot posture evaluations

Foot Posture Index

The Foot Posture Index 6 (FPI-6) is a clinical diagnostic tool used to assess weight-bearing foot posture (Hsieh et al., 2018) and has demonstrated good intra-rater reliability (0.893–0.958) (Cornwall et al., 2008). The

FPI-6 involves a visual assessment of the foot based on six criteria, each rated on a 5-point Likert scale ranging from -2 to +2. Each criterion is scored between -2 (supination) and +2 (pronation), with 0 indicating a neutral position, resulting in a total score ranging from -12 (high degree of supination) to +12 (high degree of pronation) (Tong & Kong, 2013). During the evaluation, individuals' static standing postures are observed and scored while they stand comfortably. The reference value groupings for foot posture are as follows: neutral position from 0 to +5, pronation position from +6 to +9, and +10 to +12 hyperpronation position (Hsieh et al., 2018).

Navicular Drop Test

To assess navicular drop, firstly ankle should be placed in a neutral position, and the navicular height should be measured without weight transfer. Subsequently, measurements are taken with weight transfer, without repositioning the ankle to neutral (Hsieh et al., 2018). For the navicular drop test (NDT), the individual will sit on a chair with their hips and knees flexed to 90°, and the foot will be positioned so that the subtalar joint is in a neutral position (Barton et al., 2010). The height of the navicular tuberosity relative to the ground will be measured using a ruler. Normative data for the NDT, based on similar measurements in adult populations, ranges from 6 to 9 mm. Variations exceeding 10 mm are considered abnormal (Nguyen & Shultz, 2007).

Ankle dorsiflexion evaluations

Weight Bearing Lunge Test

The test procedure was conducted based on the protocol by Hoch &McKeon (2011). Participants stood facing a wall with the test foot aligned parallel to a measuring tape fixed on the floor, ensuring that the second toes, the center of the heel, and the knees were perpendicular to the wall. During the test, the non-testing leg was positioned approximately 30 cm behind in a comfortable tandem stance to support balance. Participants were instructed to place their hands on the wall. While maintaining this position, they were directed to perform a movement bringing the knee into flexion to make contact between the front knee and the wall, while firmly pressing the heel into the ground. When participants were able to maintain contact between the heel and knee, the test foot was moved away from the wall, and the participants repeated the modified movement. Participants were advanced in 1 cm increments until they could not maintain heel and knee contact during the first movement. The maximum reach distance during the weight-bearing movement test was measured to the nearest 0.1 cm using a measuring tape fixed on the floor (Hoch &McKeon, 2011). The maximum reach distance was defined as the distance from the toe to the wall when the knee could touch the wall without lifting the heel off the ground (Bennell et al., 1998). Participants performed 3 trials for the testing leg, and the average value of these trials was recorded.

Jumping performance evaluation

Among all the multiple vertical jump tests, the DVJ enables more effective utilization of the stretch-shortening cycle particularly in the triceps surae (Bobbert et al., 1987; Bosco et al., 1982) and so appears advantageous for stimulating the function of the foot's arch spring (Tourillon et al., 2023). The CMJ without arm swing test evaluates the eccentric center jump with hands placed on the waist and measures lower extremity strength supported by the stretching-shortening cycle. Athletes squat and jump using explosive force, thereby minimizing the amortization phase, which is the transition phase between eccentric and concentric muscle contractions. The CMJ without arm swing test evaluates lower extremity strength by eliminating the contribution of the upper body (Wen et al., 2018). Considering the different measurement properties of the tests, we used both tests in our evaluation.

Before jumping performance testing, participants were asked to jog at a light, comfortable tempo for 5 minutes. Jumping performance evaluated with The Optojump system (Microgate, Bolzano, Italy), which consists of 2 parallel bars (receiver and transmitter units) with photoelectric cells positioned at ground level, allows direct surface interaction for the athlete because it can be placed on all surfaces (except sand) (Glatthorn et al., 2011). Flight time (T air) was used to calculate the height of the body's center of gravity from the ground (Sattler et al., 2012). The Optojump system showed excellent reliability and reproducibility for jumping tests (high intraclass correlation coefficient mean: 0.998) (Glatthorn et al., 2011).

Countermovement jump without arm swing test

The CMJ without arm swing test was adapted from the protocol by Pisirici et al. (2020). In the starting position, participants stood in the middle of the Optojump device with their feet open about hip-width apart. With hands on their hips, participants were instructed to squat until their thighs were parallel to the floor and then immediately jump upwards. Participants were instructed to keep their hands on their hips, extend their legs, and maintain this position throughout the jump and landing. During the test, participants wore sneakers. The CMJ without arm swing test was repeated three times, and the best value was recorded (Pisirici et al., 2020).

Drop vertical jump test

The DVJ test is derived from the protocol of Padua et al. (2009). This task involves participants jumping from a box set at a height of 30 cm to a target point placed at a distance equal to 50% of their height and then immediately rebounding for a maximum vertical jump upon landing. During the task instruction, participants were encouraged to jump as high as possible while allowing their arms to swing freely during the descent from the box. The jump is considered successful if, when landing with both feet, the participant jumps forward rather than directly down to the designated target point. If landing on one foot at the target point, the task is considered successful. The task is completed successfully if the movement is fluent, and the participant maintains a position with the head and shoulders facing forward for 5 seconds after landing (Akbari et al., 2023). The average of 3 successful trials is calculated and recorded (Padua et al., 2009).

Data Analyses

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 21.0 software package (IBM Corp., Armonk, NY, USA). The normality of the data was assessed using the Shapiro–Wilk test, and Q-Q plots. Descriptive data were presented as mean ± standard deviation (SD), minimum (min), and maximum ("max") values. One-way Analysis of Variance (ANOVA) was used to compare the numerical descriptive characteristics of the patients between groups with post-hoc Bonferroni corrections. In addition, The Games–Howell method is applicable in cases where the equivalence of variance assumption is violated.

Results

Fifty-five participants were evaluated. Seven of them had biomedical problems and were excluded. A total of 48 patients, 16 per group, completed the study without missing data. The average age of individuals participating in the neutral, prone, and hyperprone groups is 22.31 ± 2.75, 23.87± 3.72, and 22.37 ± 1.28 years, respectively, while their body mass indexes (BMI) are 22.6 ± 3, 23.4 ± 3.8 and 21.4 ± 2.24 (kg/m^2), respectively. The demographic data of the participants showed a homogeneous distribution, and the initial values of the demographic data are summarized in Table 1.

There were no significant differences in WBLT, DJT, CMJ without arm swing test, and overall, anteroposterior and mediolateral stability indexes of SPS and DPS evaluations between the groups (for all $p>0.05$). Only the NDT was shown statistically significant in all groups ($p=0.000$). Although there is a difference between the neutral and prone groups in terms of dynamic anteroposterior stability, it did not show statistical significance. The comparison of clinical parameters is summarized in Table 2.

Table 1

Demographic variables of the groups.

Variables	Neutral (n=16)	Prone (n=16)	Hyperprone (n=16)	Test (*p*)
Age (years)				
Mean ± SD	22.31 ± 2.75	23.87± 3.72	22.37 ± 1.28	*F*=1.633
(min-max)	(20-31)	(20-31)	(20-24)	*p*=0.207
Height				
Mean ± SD	1.73 ± 7.48	1.74 ± 9.42	1.71 ± 8.4	*F=0.585*
(min-max)	(1.6-1.85)	(1.6-1.88)	(1.5-1.8)	*p=0.561*
Weight				
Mean ± SD	68.3 ± 13.20	72 ± 17	64.8 ± 11	*F=1.113*
(min-max)	(52-90)	(47-94)	(43-76)	*p=0.338*
BMI (kg/m^2)				
Mean ± SD	22.6 ± 30	23.4 ± 3.8	21.4 ± 2.24	*F*=0.989
(min-max)	(17.9-28)	(17.4-29.7)	(17.9-25)	*p*=0.380

SD: Standard deviation; min: Minimum; max: Maximum; BMI: Body mass index.

Table 2

Comparison of clinical parameters between groups.

	Neutral (n=16)	Prone (n=16)	Hiperprone (n=16)	Test (*p*)
Static Postural Stability				
Overall				
Mean ± SD	1.29 ± 0.44	1.61 ± 1.21	1.83 ± 1.46	*F*=0.936
(min-max)	(0.8-2.3)	(0.6-5)	(0.8-5.7)	*p*=0.400
Anteroposterior				
Mean ± SD	0.83 ± 0.25	1.06 ± 0.82	1.02 ± 0.6	*F*=0.647
(*min-max*)	(0.5-1.2)	(0.4-3.6)	(0.5-2.6)	*p*=0.529
Mediolateral				
Mean ± SD	0.84 ± 0.46	1.25 ± 1.20	1.23 ± 1.39	*F*=0.698
(min-max)	(0.5-1.8)	(0.4-4)	(0.4-5.1)	*p*=0.503
Dynamic Postural Stability				
Overall				
Mean ± SD	1.6 ± 0.79	2.3 ± 1.17	1.98 ± 0.9	*F*=2.092
(min-max)	(0.9-3.6)	(0.8-4.70)	(0.7-3.6)	*p*=0.135
Anteroposterior				
Mean ± SD	0.88 ± 0.22	1.20 ± 0.4	0.95 ± 0.52	*F*=2.857
(min-max)	(0.5-1.3)	(0.7-1.9)	(0.4-2.3)	*p*=0.068
Mediolateral				
Mean ± SD	1.10 ± 0.88	1.63 ± 1.23	1.52 ± 0.79	*F*=1.273
(min-max)	(0.4-3.5)	(0.3-4.30)	(0.4-2.9)	*p*=0.290
NDT (cm)				
Mean ± SD	0.09 ± 0.20	0.91 ± 0.40	1.68±0.30	*F*=101.528
(min-max)	(0-0.5)	(0.3-1.5)	(1.5-2.5)	*p*=0.000
WBLT (cm)				
Mean ± SD	8.81 ± 1.99	11.25 ± 3.4	10.46 ±4.02	*F*=2.28
(min-max)	(5.5-12)	(3-16)	(4-17)	*p*=0.114
DJT height (cm)				
Mean ± SD	13.64 ± 7.53	20.83 ± 12.41	17.88 ± 12.34	*F*=1.728
(min-max)	(4-32)	(4.4-42)	(2.4-44)	*p*=0.189
CMJT height (cm)				
Mean ± SD	14.43 ± 8.02	21.10 ± 12.62	18.18 ± 11.10	*F*=1.544
(min-max)	(4.3-35.1)	(4.7-40.8)	(2.4-42.2)	*p*=0.225

SD: Standard deviation; min: Minimum; max: Maximum; NDT: Navicular drop test; WBLT: Weight-bearing lunge test; DJT: Drop jump test; CMJT: Countermovement jump without arm swing test.

Discussion

This study aimed to examine the impact of pronation of the foot on postural stability, navicular drop, ankle dorsiflexion, and jumping performance. In the results, we found that except for the navicular drop, there is no statistical difference between the groups. Our results proved there will be no differences in SPS and DPS between the groups' hypotheses however didn’t support the “while pronation amount gets higher, dorsiflexion limitation will increase and jumping performance will decrease’ hypotheses.

Postural stabilization of an upright stance is typically modeled as a single-segment, linear feedback control system that predicts ankle joint torques based on changes in ankle kinematics (Beard & Refshauge, 2020). Static postural control, or steadiness, refers to the ability to maintain the body as motionless as possible under specific conditions and positions (Goldie et al., 1989). There are conflicting results regarding static balance in individuals with subtalar joint pronation, with some studies showing improvement (Cobb et al., 2014), some showing a decrease (Cobb et al., 2004), and others showing no change (Angın et al., 2013; Bayıroğlu et al., 2024; Cote et al., 2005). In our results, consistent with the majority of the literature, no significant difference was found between the neutral, prone, and hyperprone groups in terms of postural stability assessment on one leg with eyes open.

DPS, defined as the ability to stabilize and maintain balance when transitioning from dynamic movement to a static state, is a common measure of stability in more active individuals (Goldie et al., 1989). Specifically, excessively pronated foot postures may influence peripheral (somatosensory) input via changes in joint mobility or surface contact area or, secondarily, through changes in muscular strategies to maintain a stable base of support (Letafatkar et al., 2013). However, some studies emphasize no relation between pronation posture and dynamic balance (Cote 2005; Hyong & Kang, 2016; Kim et al., 2015; Bayıroğlu et al., 2024). Our results are consistent with the literature, showing no significant difference between dynamic stability and foot posture.

Pronation is limited by the physiologic limits of the subtalar and midtarsal joint ranges of motion (Hertel et al., 2002), and maybe because those studies, similar to our results, did not find a difference between foot posture and postural stability (Hertel et al., 2002; Cote et al., 2005; Bayıroğlu et al., 2024; Hyong & Kang, 2016; Kim et al., 2015). Although not statistically significant, it has been shown that the static (Hertel et al., 2002) and dynamic (Kim et al., 2015) stability of the prone foot is lower than that of feet with normal foot posture. Additionally, individuals with a pronated foot posture require more repetitions to complete the test and have shorter balance durations on one leg compared to those with a neutral foot posture. We think that another contributing effect to these results is that most of the studies have healthy, uninjured, and young participants. The sensorimotor system can compensate for the future alternations that will cause injury. Our assumption is supported by the fact that pronated foot posture is known to alter hip (Rath, 2016) and lower extremity muscle activation (Mohammadi et al., 2017). These changes in activation patterns have been shown to potentially impair the effectiveness of movement control processes and increase the risk of injury (Mohammadi et al., 2017). To better understand the impact of pronated foot posture on postural stabilization in the future, we believe that assessments with eyes closed are necessary to challenge the sensorimotor system. We do not think that existing tests, when performed with eyes open and in a predictable, single-task manner; adequately assess the effect of pronated posture on postural stability. Supporting our view, Angın et al. found that while there was no significant difference between foot posture and postural stability with eyes open, the highest sway was observed in the pes planus group during assessments with eyes closed (Angın et al., 2013).

The NDT assesses the mobility of the medial longitudinal arch (MLA) (Hsieh et al., 2018). The amount of navicular drop is evaluated to determine the flexibility of the MLA and the position of the navicular bone with and without body weight transfer (Kısacık et al., 2021). Another method to assess foot posture is the foot posture index (FPI) and it is the most accurate way to divide the subjects into groups based on over-pronation, over-supination, and normal group (Ribeiro et al., 2011). A strong positive correlation was found between the FPI and ND (Raghav et al., 2024). Our results are parallel with the Raghav et al. (2024), we found a statistically significant difference in NDT values. Navicular drop values were parallel to the FPI classification and had increasing values from the neutral group to the hyperpronation group, confirming the increase in pronation.

Increased or prolonged pronation is commonly accepted as a risk factor and an etiological factor for increased navicular drop and faulty alignment patterns in the lower extremity (Tong & Kong, 2013; Neal et al., 2014) but it is still unclear whether DFROM limitation is compensated by subtalar joint pronation or whether the increase in the degree of pronation affects DFROM. In addition, ankle DFROM limitation reduces the ability to absorb force through the lower extremity during jumping and landing. This limitation causes higher ground reaction forces and frontal plane load, especially in the knee joint. Ankle DFROM limitation results in a decrease in vertical jumping ability (Almansoof et al., 2023). However, some studies contradict this commonly held belief (Singh et al., 2023; David et al., 2020; Zhao et al., 2017; Tourillon et al., 2023). Tourillon et al. (2023) assessed the foot's morphological deformation using one and two dimensional methods and they found that foot posture and morphological deformities were not related to DVJ kinetics. Zhao et al. (2017) found that although there is a relationship between arch height and ankle muscle strength, there is no relationship between arch height and physical performance in tasks such as agility and explosive performance. David et al. (2020) explored the relationship between the level of navicular drop and physical performance. The results showed no correlation between a high value for navicular drop (a more planus foot) and a decrease in explosive performance in the form of broad or vertical jumps. Shachez-Ramirez et al. investigated the relationship between morphological foot characteristics (foot length, forefoot width, navicular height, hindfoot width) and three different jump tests (CMJ, squat jump, DJT). When examining the correlation between morphological variables and performance in jumping activities, it was found that the only variable not showing a correlation with the DJT was navicular height (Shachez-Ramirez et al., 2020). Ramani Hardik et al. (2024) have determined that there is no connection between a pronated foot position and the vertical jump height among young recreational basketball players. Kurtoğlu et al. (2024) aimed to investigate the effect of the level of pes planus on CMJ performance parameters in amateur male and female volleyball players. The results indicated that in females, average speed, and in males, strength, both significantly affected the NDT, highlighting the importance of both factors in predicting NDT scores. Furthermore, all CMJ measurements showed significant differences between genders, but NDT scores did not (Kurtoğlu et al., 2024). Singh et al. found that flatfoot has no effect on jump height but has a significant impact on other kinetic parameters of jump performance. Players with flatfoot produced higher vertical ground reaction forces during landing which may lead to greater forces imposed on the foot region as compared to the players with normal foot which can induce various musculoskeletal injuries (Singh et al., 2023). Our results have shown that there are no significant differences in dorsiflexion angles between groups, which have been useful for assessing jump performance. Additionally, there were no differences in jump performance between groups in either the DVJ or CMJ tests. Although no differences in jump performance were observed between groups, it is known that the pronation posture affects lower extremity muscle activation. Changes in activation patterns may impair the effectiveness of movement control processes and increase susceptibility to injuries (Mohammadi et al., 2017). Future studies should investigate how muscle activation and kinetic parameters change as the amount of pronation increases during jumping.

Conclusion

Although subtalar pronation may influence static and dynamic stability as well as jumping performance during walking and running, our results suggest that the degree of subtalar joint pronation does not play a significant role in static and dynamic stability, jump performance, or DFROM in a healthy population.

Authors' Contribution

Study Design: PP; Data Collection: NK, YSM; Statistical Analysis: ÖF; Manuscript Preparation: PP, ÖF; Funds Collection: No funds.

Ethical Approval

The study was approved by the Bahcesehir University of Scientific Research and Publication Ethical Committee (E-22481095-020-343) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

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Conflict of interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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