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FACTORS AFFECTING BALL VELOCITY IN WELL-TRAINED FEMALE HANDBALL PLAYERS

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Abstract:
In this study, we aimed to analyze whether a relationship between anthropometric and physical performance characteristics and ball velocity in different throwing techniques of well-trained female handball players exists. Twelve well-trained female handball players (age, 22.47±4.57 years; body mass, 66.70±11.05 kg; height, 167.33±7.41 cm; handball experience, 9.91±3.47 years) from a local team that participated in Turkey's First Women's Handball League were recruited in this study. Anthropometric measurements, body indexes, physical performance, and ball velocity were evaluated in all subjects. A positive relationship was found between ball velocity in 9-m throw after three steps a jump and arm span, bi-iliac breadth, and bi-acromial breadth (r^2=0.49; p=0.03, r^2=0.50; p=0.03 and r^2=0.57; p=0.02, respectively) as well as between ball velocity in 9-m throw after three steps and a jump and Monourier index (r^2=0.52; p<0.04). Ball velocity in 9-m throw after three steps and a jump was negatively related to Cormic index (r^2=-0.52; p<0.04). Multiple linear regression analysis showed that all performance parameters affect neither the 7-m throw (R=0.85, R^2=0.73; $F_{(4-7)}$=1.61; p>0.33) nor the 9-m throw three steps after and a jump (R=0.88, R^2=0.77; $F_{(4-7)}$=1.96; p>0.26). However, a moderate positive relationship between 9-m throw after three steps and a jump and grip strength (r=0.54; p=0.03) and vertical jump height (r=0.53; p=0.03) was noted. Neither 7-m standing throw nor 9-m throw after three steps and a jump correlated with other variables. Arm span, bi-iliac breadth, bi-acromial breadth, Monourier index score, Cormic index score, vertical jump height, and grip strength may have a positive or negative effect on 9-m throw after three steps and a jump in well-trained female handball players. The results of this study may be useful in the identification of handball skills.

Keywords: handball, ball velocity, anthropometry, physical performance

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1. Introduction

Handball is a team sport characterized by full body contact with the opponent and high-intensity intermittent actions, including sprinting, jumping, changing directions, hitting, throwing block, and pushing, followed by a low-intensity recovery period (Gobadi et al., 2013; Saavedra et al., 2020; Saavedra et al., 2018). It is a multifactorial sport; thus, success is determined by a variety of technical and tactical, mental, anthropometric (height, weight, muscle mass, fat percentage, length of extremities, etc.), and physical performance capacity, such as speed, change of direction (COD), power, strength, and intermittent endurance (Hoppe et al., 2017; Vila et al., 2012).

Physical performance capacity, techniques, and handball-specific skills are affected by the anthropometric characteristics of the players (Saavedra et al., 2018; Michalsik & Aagaard, 2015; Milanese et al., 2011) Saavedra et al. (2018) reported that stature is important for throwing and blocking and a relatively body mass for one-on-one actions. According to Camacho-Cardenosa et al. (2018) a longer arm span facilitates the occupation of spaces in defensive and offensive actions. Regarding body composition, Granados et al. (2007) demonstrated that a greater fat-free mass is associated with better performance because of the increased muscular power and strength.

The team objective in handball is to score a goal, which can only be achieved by throwing the ball accurately at a high velocity (Vila & Ferragut, 2019) The most common throwing techniques used in competitions are jump throws (73–75%), standing throw with run-up (14–18%), penalty throw (6–9%), diving throw (2–4%), and direct free throw (1%) (Çikmaz et al., 2005).

In this study, we aimed to analyze whether a relationship between anthropometric and physical performance characteristics and ball velocity in different throwing techniques of well-trained female handball players exists.

2. Methods

This study was conducted in accordance with the ethical standards of the Declaration of Helsinki and was approved by the Tekirdag Namik Kemal University Ethics Committee (Research protocol number: 2021.72.03.12). The subjects received a verbal explanation of the experimental design and signed an informed consent form before participating in this study.

2.1 Subjects

Twelve well-trained female players from a local handball team that participated in the Turkey's First Women's Handball League were recruited in this study. The team finished third place in the competition, and they aim to be part of Turkey's Women's Handball Super League in the next season. Players' characteristics are presented in Table 1. The inclusion criteria were as follows: a professional handball license for at least 4 years, which covers the 2020–2021 handball season; age ≥18 years; healthy based on the medical examination for a handball license for the 2020–2021 handball season; and no recent musculoskeletal injuries.

Table 1: Descriptive Characteristics of the Players (N=12)

Variables	Mean± SD
Age (years)	22.47 ± 4.57
Body mass (kg)	66.70 ± 11.05
Height (cm)	167.33 ± 7.41
Handball experience (years)	9.91 ± 3.47
Training frequency, weekly	7.75 ± 0.86
Training volume (h/week)	15.50 ± 1.73

2.2 Procedures

All subjects underwent a set of anthropometric measurements, physical fitness tests, and ball velocity evaluation in 7-m standing throw and 9-m throw after three steps and a jump. All tests were performed on the same day (2.30–4.30 PM) at the Tekirdag Namik Kemal University Sports Hall. The team was in the mid-season; however, they had a short break due to the COVID-19 pandemic. All subjects were well rested a day before the tests and were instructed to continue their normal food consumption, fluid intake, and regular sleep pattern. However, caffeine and food intake 3 h prior to the tests were not allowed. Evaluations were performed in the following order: body mass, body composition (muscle mass and fat percentage), height measurement, and anthropometric measurements; reactive jump test, reactive strength index, and leg stiffness (based on vertical jump height); 7-m standing throw and 9-m throw after three steps and a jump; grip strength; 20-m sprint; and pro-agility test. The test order was according to the study of Saavedra et al., (2020). Each subject had a 5-min recovery period between tests, and the subjects were not allowed to perform static stretching during the recovery period. During the tests, the subjects were instructed to wear sport shorts, short-sleeved t-shirts, and handball shoes. However, all anthropometric measurements were performed barefoot.

2.3 Anthropometry

Body mass and body composition (muscle mass [in kg] and fat percentage) were measured using the bioelectric impedance method (BIA). The BIA device (Tanita BC 545N) works according to the hand-to-hand and foot-to-foot principle. Standing and sitting heights were measured using a stadiometer (13539; Mesilife). Bi-iliac breadth, bi-acromial breadth, hand length, and hand breadth were measured on the dominant side using an anthropometric set (HLT-100; Holtain Ltd.). Arm span and leg length (dominant side) were evaluated using a fiberglass measuring tape.

Body indexes were calculated as follows (Çikmaz et al., 2005): arm span index (%) (arm span/height), leg index ([100×leg length]/height), Cormic index (%) ([sitting height/height] ×100), Monourier index (%) ([height−sitting height/sitting height] ×100), bi-acromial index (%) (bi-acromial breadth/height] ×100), and hip index (%) ([bi-iliac breadth/height] ×100).

The leg index shows leg length as a proportion of the height. The Cormic index shows trunk size as a proportion of the height. The Monourier index shows leg length as a proportion of the trunk size. The hip index shows hip width as a proportion of the height. In this study, body indexes were interpreted according to the study of Özer (2009).

2.4 Warm-up

Before the tests, the subjects performed a 15-min warm-up session, which included 10 min of self-paced jogging within the handball field (similar to that performed prior to each handball training or match) and 5 min of dynamic stretching exercises, which consisted of front kicks with hand reach, walking lunges, high knee skipping, and butt kicks. Each exercise was performed twice on a 20-m line.

2.5 Reactive jump test

Vertical jump height (VJH), reactive strength index (RSI), ground contact time (GCT), and leg stiffness (K_{leg}) were measured using a Myotest Pro system accelerometer (Myotest SA, Switzerland). The Myotest Pro system offers several performance tests, such as half squats, reactive jump test tests, countermovement jumps, and squat jumps, to assess an athlete's performance (Laffaye et al., 2016). After recording the body mass of the subjects to the device, the device was attached to the belt and fixed vertically. The subjects were instructed to hop in place five times, as high as possible while reducing GCT, with minimal knee flexion and maximal jump height when they hear the acoustic signal sounds. After the last jump, they were instructed to return to a vertical standing posture and wait for the final acoustic signal (Laffaye et al., 2016). The reactive jump test was completed after the final signal. The RSI, K_{leg}, GCT, and VJH were automatically calculated by the device. The procedure was performed twice, with a 3-min rest in between. The best score obtained from the two treatments was used for the statistical analysis.

2.6 Ball velocity

Ball velocity was measured with a speed radar (SpeedTrac X Sport Radar-5200, Canada), which was placed behind the goal (Saavedra et al., 2018). Ball velocity was recorded during a 7-m standing throw and 9-m throw after three steps and a jump (Saavedra et al., 2018). Each of the throwing techniques was performed twice without opposition with a 20-s rest interval; the better score was recorded (in km/h) and used in the statistical analyses (Saavedra et al., 2018). Each subject had a 2-min rest between the different throwing techniques.

2.7 Grip strength

Hand grip strength on the dominant side was measured using a hand grip dynamometer (Takei Scientific Instruments Co., Ltd., Japan). During the test, the upper limb was straight and pointing downward (Lijewski et al., 2019). The dynamometer was squeezed maximally, and the contraction was maintained for 5 s (Hammami et al., 2019). No ancillary body movements were allowed (Hammami et al., 2019). Two trials were separated by a 45-s interval, and the better score was recorded for the statistical analysis.

2.8 Sprint (20 m)

The subjects performed a 20-m sprint and the time was recorded using a photocell gate (Newtest Powertimer 300-series, Oy, Finland). The test started with the subject in a standing position and with the front foot placed 0.2 m from the first photocell gate (Hernández-Davo et al., 2021). Two trials were separated by a 3-min recovery period, and the better score was recorded for the statistical analysis.

2.9 Pro-agility test

The test started with the subject in a neutral stance. Thereafter, the subject was instructed to sprint to either the dominant or non-dominant side first and touch a cone that was placed 5 m away from the starting point. Subsequently, they were asked to run to the opposite side, touch the farthest cone at 10 m, and perform a 5-m sprint towards the finish line (Hernández-Davo et al., 2021). Time was recorded using photocell gates (Newtest Powertimer 300-series, Oy, Finland). The subjects performed two trials on the dominant side, and the fastest times were used for the analysis. The subjects had a 3-min recovery period between trials.

2.10 Statistical analysis

All data in this study were analyzed using SPSS 18 (Statistics Package for Social Sciences; SPSS Inc., Chicago, IL, USA). Descriptive statistics (mean and standard deviation) of the data were calculated. Normality of the data was determined by calculating the skewness and kurtosis (−1.5, +1.5) values; all data showed a normal distribution (Tabachnick & Fidell, 2013). Whether dependent variables, such as 7-m standing throw and 9-m throw after three steps and a jump, were affected by anthropometric variables, body indexes, and physical performance components was determined using multiple linear regression analysis. Before proceeding to regression analysis and interpretation of the findings, we examined whether homogeneity of linearity assumptions and multiple and variance–covariance matrices exist (Tabachnick & Fidell, 2013). Moreover, whether the relationships between the dependent variables were linear or not was evaluated by scatter plots; linearity assumption was observed between each dependent variable. Another important assumption that regression is based on is that there is a linearity between dependent variables, that is, this relationship between independent variables is not high (multicollinearity). To control the probability of predictive variables, tolerance and variance inflation factor values were calculated for all factors. A tolerance value <0.10 and variance inflation factor value >10 indicate a strong relationship between the independent variables (Dormann et al., 2013); multiple linear regression analysis was employed for variables that supply such condition. Moreover, Pearson moment correlation coefficient analysis was used to determine the relationships between variables that did not meet the multiple linear regression analysis requirements. Alpha levels <0.05 were considered significant.

3. Results

The relationship among anthropometric characteristics, body indexes, 7-m standing throw, and 9-m throw after three steps and a jump are presented in Tables II and III. Ball velocity prediction in 7-m standing throw and 9-m throw after three steps and a jump based on physical performance components are presented in Tables IV and V, respectively. Body indexes were interpreted according to the study of Özer (2009) (Table III). The subjects had longer trunks than normal based on the Cormic index, and their trunks were narrower than normal based on the bi-acromial index. Moreover, the subjects were found to be mesotiskelie (medium-sized leg length in proportion to the trunk) based on the Monourier index. For the leg and hip indexes, the subjects had shorter lower extremities than normal and wider hips than normal.

Table 2: Relationship between Anthropometric Characteristics and 7-m Standing Throw and 9-m Throw after Three Steps and a Jump

Variables	**Mean ± SD**	**r1** (Ball velocity: 50.08±12.82 km/h)	**r2** (Ball velocity: 64.41±5.58 km/h)
Height (cm)	167.33 ± 7.41	−0.24	0.37
Body mass (kg)	66.70 ± 11.05	−0.30	0.01
Body fat (%)	24.56 ± 5.71	−0.07	0.00
Muscle mass (kg)	47.80 ± 4.43	−0.42	0.00
Sitting height (cm)	89.10 ± 3.03	−0.38	−0.00
Arm span (cm)	168.66 ± 7.66	−0.33	0.49*
Bi-iliac breadth (cm)	33.20 ± 3.57	−0.09	0.50*
Bi-acromial breadth (cm)	24.42 ± 2.18	−0.16	0.57*
Hand length (cm)	8.40 ± 0.89	−0.30	0.47
Hand breadth (cm)	8.24 ± 0.40	−0.15	0.27
Leg length (cm)	88.25 ± 4.99	−0.18	0.31

Note: r1, relationship between anthropometric characteristics and 7-m standing throw; r2, relationship between anthropometric characteristics and 9-m throw after three steps and a jump
*p<0.05

No relationship between anthropometric variables and 7-m standing throw performance was observed ($p>0.05$). A moderate positive relationship was found between arm span, bi-iliac breadth, as well as bi-acromial breadth and 9-m throw after three steps and a jump ($r^2=0.49$; $p=0.03$, $r^2=0.50$; $p=0.03$ and $r=0.57$; $p=0.02$, respectively). Other anthropometric variables were not related to and 9-m throw after three steps and a jump ($p>0.05$).

Table 3: Relationship between Body Indexes and 7-m Standing Throw and 9-m Throw after Three Steps and a Jump

Variables	**Mean ± SD**	**r1** (Ball velocity: 50.08±12.82 km/h)	**r2** (Ball velocity: 64.41±5.58 km/h)
BMI (kg/cm^2)	23.80 ± 3.55	−0.19	−0.19
Arm span index (%)	1.00 ± 0.02	−0.18	0.33
Leg index (%)	52.72±1.37	0.01	0.02
Cormic index (%)	53.29 ± 1.66	−0.06	−0.52*
Monourier index (%)	87.79 ± 5.87	0.05	0.52*
Bi-acromial index (%)	14.59 ± 1.11	−0.05	0.44
Hip index (%)	19.85 ± 2.10	0.01	0.34
Ponderal index ($cm/kg^{0.333}$)	14.25 ± 2.26	−0.09	−0.29

Note: BMI, body mass index; r1, relationship between anthropometric characteristics and 7-m standing throw; r2, relationship between anthropometric characteristics and 9-m throw after three steps and a jump
*p<0.05

Moreover, no relationship between body indexes and 7-m standing throw was found ($p>0.05$). A moderate negative relationship was observed between Cormic index and 9-m throw after three steps and a jump ($r^2=-0.52$; $p<0.04$), whereas a moderate positive relationship was noted between Monourier index and 9-m throw after three steps and a jump ($r^2=0.52$; $p<0.04$). No other body indexes were related to 9-m throw after three steps and a jump ($p>0.05$).

Table 4: Ball Velocity Prediction in 7-m Standing Throw Based on Physical Performance Components

Variables	Mean ± SD	B	Std. Error	β	t	p	Zero-order r
(Constant)	-	197.36	105.93	-	1.86	0.13	-
Grip strength (kg)	32.58 ± 5.09	−2.01	1.02	−0.79	−1.96	0.12	−0.05
20-m sprint (s)	4.20 ± 0.19	−13.86	70.83	−0.21	−0.19	0.85	−0.13
Pro-agility test (s)	5.38 ± 0.25	−19.97	50.14	−0.39	−0.39	0.71	−0.43
Vertical jump height (cm)	30.55 ± 8.15	1.55	0.68	0.98	2.25	0.08	0.07
Ground contact time (ms)	161.56 ± 51.59	0.10	0.17	0.43	0.63	0.56	0.10
Reactive strength index (mm/ms)	2.77 ± 0.65	−1.98	13.64	−0.10	−0.14	0.89	0.32
Leg stiffness (N/m)	23.68 ± 15.87	1.04	1.09	1.29	0.95	0.39	0.31
R=0.85	R^2=0.73						
$F_{(4-7)}$=1.61	p=0.33						

Note: SD, standard deviation

Multiple linear regression analysis showed that the common effect of all performance parameters does not explain the change in 7-m standing throw (R=0.85, R^2=0.73; $F_{(4-7)}$=1.61; p>0.33). No relationship between predictive variables and 7-m standing throw performance was found (p>0.05).

Table 5: Ball Velocity Prediction in 9-m Throw after Three Steps and a Jump Based on Physical Performance Components

Variables	Mean ± SD	B	Std. Error	β	t	p	Zero-order r
(Constant)	-	53.10	42.80	-	1.24	0.28	-
Grip strength (kg)	32.58 ± 5.09	0.16	0.41	0.14	0.39	0.71	0.54
20-m sprint (s)	4.20 ± 0.19	−48.06	28.62	−1.68	−1.67	0.16	−0.26
Pro-agility test (s)	5.38 ± 0.25	31.51	20.26	1.43	1.55	0.19	−0.23
Vertical jump height (cm)	30.55 ± 8.15	0.75	0.27	1.10	2.71	0.06	0.53
Ground contact time (ms)	161.56 ±5 1.59	0.10	0.06	0.97	1.53	0.19	−0.43
Reactive strength index (mm/ms)	2.77 ± 0.65	−8.37	5.51	−0.97	−1.51	0.20	0.01
Leg stiffness (N/m)	23.68 ± 15.87	0.90	0.44	2.58	2.06	0.10	0.16
R=0.88	R^2=0.77						
$F_{(4-7)}$=1.96	p=0.26						

Note: SD, standard deviation.

Similarly, multiple linear regression analysis showed that the common effect of all performance parameters does not explain the change in 9-m throw after three steps and a jump (R=0.88, R^2=0.77; $F_{(4-7)}$=1.96; p>0.26). However, grip strength (r=0.54; p=0.03) and VJH (r=0.53; p=0.03) showed a moderate positive relationship with 9-m throw after three steps and jump performance. No relationship was found between other variables and 9-m throw after three steps and a jump.

4. Discussion

This study aimed to analyze whether anthropometric features and physical performance characteristics are related to ball velocity in different throwing techniques of well-trained female handball players. The main findings of this study are as follows: a) ball velocity in 9-m throw after three steps and a jump is related to arm span, bi-iliac breadth, and bi-acromial breadth, b) Monourier index is positively related to ball velocity in 9-m throw after three steps and a jump, c) Cormic index is negatively related to ball velocity in 9-m throw after three steps and a jump, and d) grip strength and jumping height are good predictors of ball velocity in 9-m throw after three steps and a jump.

In women's handball, stature is important for throwing velocity and blocking and a relatively body mass for one-on-one actions (Shalfawi et al., 2014). Beside stature and body mass, lean body mass and body mass index (BMI) are also accepted as general anthropometric variables (Zapartidis et al., 2009; Skoufas et al., 2003). Perimeter, hand breadth, finger span, ring finger length, middle finger length, and arm span are accepted as handball-specific anthropometric variables (Skoufas et al., 2003). Previous studies reported that general anthropometric variables are better predictors than handball-specific anthropometric variables (Camacho-Cardenosa et al., 2018; Zapartidis et al., 2009; Skoufas et al., 2003; Debanne & Laffaye, 2011). Nevertheless, Zapartidis et al. (Zapartidis et al., 2011) found that, except for BMI, body height, arm span, hand length, and body mass are positively correlated with ball velocity in 7-m standing throw. Debanne and Laffaye (2011) also reported that body mass, height, lean mass, BMI, and arm span correlated with thrown velocity in overarm throw in a standing position. In our study, a positive relationship was found between arm span, bi-iliac breadth, as well as bi-acromial breadth and 9-m throw after three steps and a jump. The difference between the findings in our study and those in the previous studies could be attributed to sex differences, age, and playing experience (Özer, 2009; Lijewski et al., 2019; Zapartidis et al., 2009; Zapartidis et al., 2011). Our study's results are consistent with those of Camacho-Cardenosa et al., (2018), Skoufas et al., (2003) and Eliasz and Wit (1996), specifically regarding the positive relationship of arm span and bi-acromial breadth with ball velocity.

Our study also found a positive relationship between ball velocity in 9-m throw after three steps and a jump and Monourier index and a negative relationship between ball velocity in 9-m throw after three steps and a jump and Cormic index. As previously mentioned, the subjects in this study had longer trunks than normal based on the Cormic index and were mesotiskelie (i.e., medium-sized leg length in proportion to the trunk) based on the Monourier index. According to these results, a short trunk and medium-sized leg length are advantageous for ball velocity in 9-m throw after three steps and a jump. However, no previous reports that could support our results on the relationship of Cormic index and Monourier index with ball velocity have been conducted. Nevertheless, Lijewski et al. (2019) demonstrated higher-frequency movements in those with short lower extremities, which, in turn, is associated with increased speed over a short distance and increased ball velocity.

In handball, ball velocity and throw accuracy are also affected by muscular strength and power (Saavedra et al., 2018; Zapartidis et al., 2009; Debanne & Laffaye, 2011; Zapartidis et al., 2011). Tests for grip strength, medicine ball throw, and different jumping techniques (such as countermovement jump, vertical jump, squat jump, and long jump) as well as 10–30-m sprint tests are simple methods to evaluate muscular strength and power of athletes (Saavedra et al., 2018; Lijewski et al., 2019; Zapartidis et al., 2009; Debanne & Laffaye, 2011; Zapartidis et al., 2011). According to Andrade et al., (2014) dynamometry is a good test to evaluate handball players' strength and, in female players, has been shown to have a good correlation with the isokinetic strength of shoulder rotator muscles. Some researchers agree that a higher hand grip strength involves a greater control of the ball and that a good grasp has a positive influence on ball speed (Camacho-Cardenosa, 2018; Vila & Ferragut, 2019) According to previous studies, (Camacho-Cardenosa, 2018; Vila & Ferragut, 2019; Lijewski et al., 2019; Ferragut et al., 2018). grip strength is positively correlated with ball velocity and throw accuracy. Hence, based on the previous studies, the moderate positive relationship between grip strength and 9-m throw after three steps and a jump performance in our study is expected.

Jump and sprint tests (10–30 m) could be the most used evaluation strategy for muscular power performance because they are simple and time-saving and do not require complex and expensive test devices. (Saavedra et al., 2018; Zapartidis et al., 2009; Zapartidis et al., 2011; Forthomme et al., 2005). Zapartidis et al. (2011) reported that ball velocity in 7-m standing throw is significantly correlated with 30-m sprint and long jump. Alves and Marques (2013) found that countermovement jump and 30-m sprint are correlated with ball velocity in over arm throw with a three-step running throw. Saavedra et al. (2018) also reported that a countermovement jump is correlated with ball velocity in 7-m standing throw and 9-m throw after three steps and a jump. Our results showed a positive relationship between VJH and 9-m throw after three steps and a jump; however, no relationship between 20-m sprint and ball velocity in 7-m standing throw as well as in 9-m throw after three steps and a jump was found.

5. Study limitations

This study has several limitations. We did not use statistical power analysis; thus, the small sample size may be a limitation. Using a larger sample size may have yielded different results. We completed all measurements on the same day, and physical performance tests may have negatively or positively affected one another. Based on the results of the study, we could not explain the absence of relationship between any anthropometric features or physical performance parameters and ball velocity in 7-m standing throw; hence, further investigations are warranted.

6. Conclusions

No consensus regarding the relationship between ball velocity in different throw techniques and anthropometric and physical performance variables based on subject characteristics, such as sex, age, playing experience, and body composition, has been established in the literature. Our study showed that arm span, bi-iliac breadth, bi-acromial breadth, Monourier index, Cormic index, VJH, and grip strength may have a positive or negative effect on 9-m throw after three steps and a jump in well-trained female handball players. The results of our study could be useful in identifying potential skills for handball or in designing handball training plans.

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Authors' contribution
Data collection: Umut Canlı; methodology: Umut Canlı and Cem Kurt; fund collection: Umut Canlı and Cem Kurt; writing – original draft preparation: Umut Canlı and Cem Kurt; writing – review and editing: Umut Canlı and Cem Kurt. All authors read and approved the final version of the manuscript.

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Conflicts of interest statement
The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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