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CHANGES IN THE RELATIONSHIPS BETWEEN POMOLOGICAL CHARACTERISTICS IN HAZELNUTS ACCORDING TO THE PICKING MANUALLY FROM THE BRANCH AND THE GROUND

Saim Zeki BOSTAN[1]*

[1] Ordu University, Faculty of Agriculture, Department of Horticulture, Ordu-Türkiye

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* CONTACT

szbostan@hotmail.com

A B S T R A C T

This research was carried out to determine the relationships between pomological characteristics of hazelnuts collected manually from the branch and the ground. The research was carried out in three different orchards belonging to a producer, which contains Tombul, Foşa and Çakıldak hazelnut varieties in Kocaali district of Sakarya province (Türkiye). The orchards, located at an altitude of 300 m, face north. Hazelnut samples of Tombul, Foşa and Çakıldak varieties were collected from the branch in the first (2009) and second year (2010), on 12-15 August, 15-18 August and 22-25 August, respectively, and from the ground on 24-27 August, 27-30 August and 4-7 September, respectively. Nut weight, nut size, shell thickness, kernel weight, kernel size, kernel cavity, kernel percent, shriveled kernel ratio, good kernel ratio, full and average blanching ratios were determined in dried fruits. Correlation analysis was performed between the properties examined separately in the two groups of samples. In the samples collected from the branch and the ground, the highest variation was seen in the shriveled kernel ratio and the lowest in the good kernel ratio. It was determined that all of the significant correlation coefficients in the samples collected from the branch were positive, and the highest correlation coefficients were between full blanching ratio-average blanching ratio, nut weight-kernel weight and nut size-kernel size, respectively. In the samples collected from the ground, more significant correlations, and also negative significant relationships were found between the investigated properties. It was determined that the highest positive correlations were found between nut size-kernel weight, nut weight-kernel weight, full blanching rate-average blanching rate, nut weight-kernel size and nut size-kernel size, respectively; the highest negative correlations were found between the shell thickness-good kernel ratio, the shell thickness-kernel size, and the shriveled kernel ratio-good kernel core ratio, respectively. It can be said that the samples collected manually from the ground in hazelnut were more homogeneous than those collected from the branch in terms of the quality characteristics examined; in the samples collected from the ground, the good kernel ratio and kernel size were negatively affected by the shell thickness, the shriveled kernel ratio was positively affected, and there were no differences between the samples in terms of other relations.

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ORCID> 0000-0001-6398-1916 (SZB)

1. Introduction

Harvesting hazelnuts is currently one of the most expensive processes in the production cycle, adding up to 40-60% of the production cost and is quite time-consuming when done manually. The degree of mechanization also depends significantly on the land topography (Bernardi et al., 2017). Since the 1980s, mechanical harvesting has almost completely replaced manual harvesting in developed countries, and mechanical harvesting machines have also continuously improved during this period. The transition to machine harvesting has caused some important changes in hazelnut production techniques (Monarca et al., 2013).

In Türkiye, which is the leader of the world hazelnut production and trade, harvesting is generally done by hand in the 1st standard region, and generally by machine in the 2nd standard region (İslam, 2018). Although shaking and picking from the ground is considered the best method for manual collection, this is not possible on sloping lands. On the other hand, shaking and picking from the ground seem to be more positive in terms of efficiency and quality than picking from the branch by hand (Çırak and Bostan, 2018). Due to topographic conditions, hand picking from the branch is the most common method in the region. In this method, care should be taken not to damage the buds that will produce crops the next year.

Correlation is one of the important biometric tools that measures the degree and magnitude of the relationship between various features (Sharma, 2003). Phenotypic correlation and heritability are important parameters that researchers should consider in breeding programs (Valentini et al., 2004). Estimates of correlation coefficients allow direct versus indirect selection to be compared and to obtain information about the second trait associated with the first trait (Falconer and Mackay, 1996).

It has been stated in studies on hazelnut yield, yield parameters and fruit quality characteristics that there are many simple or phenotypic correlations of the morphological features examined and that the correlations between the parameters generally vary according to species, varieties, genotypes and years (Bostan, 2022).

The formation of defective fruits in hazelnuts may be related to both pre-harvest, during and post-harvest processes. For this reason, it is important to first know these defects and their causes and then take precautions against them in a timely manner (Bostan, 2019).

Although many studies have been conducted on the relationships between pomological characteristics in hazelnuts, no study has been found that reveals the relationships between the quality characteristics of hazelnuts harvested according to different methods. This study was conducted to reveal the relationships between the important pomological properties of hazelnut samples collected manually from the branch and the ground. Thus, it was aimed to determine the homogeneity and interdependence of quality characteristics of hazelnut samples collected by hand from the branch and the ground.

2. Material and methods

2.1. Plant materials

The research was carried out in three different orchards belonging to one producer, in the 'Ocak' planting system, in the Kocaali district of Sakarya province of Türkiye, containing Tombul, Foşa and Çakıldak hazelnut varieties. The orchards, located at an altitude of 300 m, are oriented towards the north and are in complete yield age (40-55 years).

Cultural practices (suckers cutting, disease and pest control, fertilization) are carried out regularly in the orchards.

Standard soil analyzes performed on soil samples taken from the orchards at a depth of 0-30 cm revealed that all three orchard soils were very acidic in character (pH: 4.62-4.90), clayey loamy in structure (60-65%), unsalted (0.42-0.58 dSm^{-1}), low in lime (0.1%), moderate in organic matter 2.07-2.46%), good in nitrogen (0.10-0.12%) and insufficient in phosphorus (4-5 ppm).

2.2. Methods

Before harvest, the ocaks were determined for branch and ground collection practices, 3 varieties, 3 orchards, 3 repetitions and 3 in each repetition. Accordingly, all of the clusters were collected from a total of 27 ocaks from 3 orchards for 1 variety and 1 application in every two years.

First, in each orchard, the ocaks where the clusters would be collected from the ground were randomly determined. Then, the clusters in the ocaks around them were collected by hand, thus preventing the samples in the ocaks from mixing with each other. The fruits were harvested when the husks turned yellow and reddened, the nuts began to move inside the husk and ¾ of the hard shell turned red (Okay et al., 1986).

Hazelnut samples of Tombul, Foşa and Çakıldak varieties were collected from the branch in the first (2009) and second year (2010), on 12-15 August, 15-18 August and 22-25 August, respectively, and from the ground on 24-27 August, 27-30 August and 4-7 September, respectively. The samples from each orchard and variety were grouped separately on the basis of repetition, and all clusters in the ocaks were evaluated.

The clusters collected from the branch was kept in the sun for an average of 3 days in the grass threshing floor, then sorted manually, and the nuts dried in the sun again for 5 days. The fruit collected as nut from the ground were brought directly to the drying floor and left to dry in the sun.

In dried nuts, nut weight, nut size (the arithmetic average of the width, length and thickness), shell thickness, kernel weight, kernel size (the arithmetic average of the width, length and thickness), internal cavity, kernel percentage, shriveled kernel ratio, good kernel ratio, and full and average blanching rates (incubated at 175 °C for 15 min) (Bostan and İslam, 1999a) were determined.

2.3. Experimental design and statistical analysis

The experimental design was planned in random plots with 3 replications. Two years' data were evaluated in statistical analyses.

Correlation analysis was performed in the SAS JMP 13.2.0 (US, Canada) statistical program to determine the relationships between the pomological characteristics examined in hazelnuts.

3. Results

In the research, analyzes and evaluations of hazelnuts collected from the branch and the ground were made separately.

3.1. The samples collecting from branch

The mean, standard deviation (SD), minimum, maximum and coefficient of variation (CV) values of hazelnuts collected from the branch are presented in Table 1.

Table 1. Simple univariate statistics of the traits examined in hazelnuts collected from the branch

Traits	Abbreviation	Mean	SD	Min.	Max.	CV (%)
Nut weight (g)	NW	2.12	0.23	1.63	2.90	10.77
Nut size (mm)	NS	16.93	0.92	14.56	18.52	5.43
Shell thickness (mm)	ST	1.45	0.18	1.18	2.04	12.69
Kernel weight (g)	KW	1.14	0.13	0.89	1.52	11.22
Kernel size (mm)	KS	13.07	0.75	11.00	14.61	5.75
Kernel cavity (mm)	IC	3.78	1.17	0.54	5.96	30.99
Kernel percentage (%)	KP	53.57	2.96	47.80	59.81	5.52
Shriveled kernel (%)	SK	2.78	3.46	0.00	15.00	74.55
Good kernel (%)	GK	92.31	4.09	80.00	100.00	4.43
Full blanching (%)	FB	75.09	25.69	10.00	100.00	33.43
Average blanching (%)	AB	88.24	17.56	20.00	100.00	19.90

In the samples collected from the branch, the highest variation was seen in the shriveled kernel ratio (74.55%) and the lowest in the plump interior ratio (4.43%). The coefficients of variation of shriveled kernel, full blanching and kernel cavity were determined to be over 20%. The coefficient of variation remained below 10% in terms of good kernel ratio, nut and kernel sizes. The correlation analysis performed for the samples collected from the branch showed that all of the significant relationships among the examined features were positive, and the highest relationships (over 77%) were full blanching ratio-average blanching ratio (91.1%), nut weight-kernel weight (87.4%) and nut size-kernel size (%). 77.5) (Table 2).

Table 2. Simple correlation coefficients and significance levels between the traits examined in hazelnuts collected from the branch

	NW	NS	ST	KW	KS	IC	KP	SK	GK	FB
NS	0.497**									
ST	0.097	-0.206								
KW	0.874***	0.524***	0.017							
KS	0.354**	0.775***	-0.226	0.440**						
IC	0.538***	0.692***	0.019	0.524***	0.663***					
KP	-0.163	0.101	-0.155	0.336*	0.207	0.027				
SK	-0.141	0.029	0.023	-0.227	-0.042	0.086	-0.175			
GK	0.327*	0.311*	-0.044	0.387**	0.330*	0.313*	0.132	-0.230		
FB	0.226	0.098	0.182	0.158	-0.024	0.037	-0.125	-0.123	0.053	
AB	0.174	-0.020	0.193	0.100	-0.092	-0.007	-0.140	-0.185	0.057	0.911***

Sign.: *= 5%, **= 1%, ***= 1‰

On the other hand, nut size-kernel cavity (69.2%), kernel size-internal cavity (66.3%), nut weight-kernel cavity (53.8%), nut size-kernel weight and kernel weight-internal cavity (52.4%), nut weight-nut size (49.7%), kernel weight-kernel size (44%), kernel weight-good kernel ratio (38.7%), nut weight-kernel size (35.4%), kernel weight-kernel percentage (33.6%), kernel size-good kernel ratio (33.0%), nut weight-good kernel ratio (32.7%), good kernel ratio-kernel cavity (31.3%) and nut size-good kernel ratio (31.1%) relationships were also found to be significant, respectively.

3.2. The samples collecting from ground

The mean, standard deviation (SD), minimum, maximum and coefficient of variation (CV) values of hazelnuts collected from the ground are presented in Table 3.

Table 3. Simple univariate statistics of the traits examined in hazelnuts collected from the ground

Traits	Abbreviation	Mean	SD	Min.	Max.	CV (%)
Nut weight (g)	NW	2.19	0.17	1.87	2.61	7.60
Nut size (mm)	NS	17.28	0.83	15.36	18.78	4.79
Shell thickness (mm)	ST	1.29	0.15	0.93	1.62	11.92
Kernel weight (g)	KW	1.17	0.11	0.91	1.37	9.63
Kernel size (mm)	KS	13.25	0.69	11.83	14.76	5.20
Kernel cavity (mm)	IC	3.37	1.67	0.33	11.10	49.71
Kernel percentage (%)	KP	53.57	3.12	47.14	60.48	5.82
Shriveled kernel (%)	SK	1.20	2.56	0.00	10.00	83.55
Good kernel (%)	GK	96.67	4.00	85.00	100.00	4.14
Full blanching (%)	FB	87.30	15.84	20.00	100.00	18.14
Average blanching (%)	AB	95.37	7.41	68.00	100.00	7.77

In the samples collected from the ground, as in those collected from the branches, the highest variation was observed in the shriveled kernel ratio (83.55%) and the lowest in the good kernel ratio (4.14%). In addition to the shriveled kernel ratio, the variation in the kernel cavity was determined to be over 20%, and in addition to the good kernel ratio, the weight and size of the nut and kernel, the kernel percentage and the average blanching ratio were determined to be below 10%. Variation was generally lower in samples collected from the ground.

Correlation analysis in the samples collected from the ground revealed that there were more significant relationships and negative significant relationships among the examined features, unlike those collected from the branch (Table 4).

Table 4. Simple correlation coefficients and significance levels between the traits examined in hazelnuts collected from the ground

	NW	NS	ST	KW	KS	IC	KP	SK	GK	FB
NS	0.790***									
ST	0.066	-0.133								
KW	0.807***	0.835***	-0.050							
KS	0.520***	0.762***	-0.304*	0.655***						
IC	0.415**	0.441**	0.205	0.457**	0.347*					
KP	0.060	0.380**	-0.188	0.637***	0.433**	0.239				
SK	-0.098	-0.070	0.450**	-0.035	-0.151	-0.011	0.067			
GK	0.089	0.143	-0.351**	0.304*	0.262	0.147	0.407**	-0.292*		
FB	0.132	0.120	0.100	0.194	0.085	0.170	0.152	-0.011	0.108	
AB	0.081	-0.088	0.254	0.033	-0.090	0.099	-0.057	0.031	0.027	0.786***

Significance: *= 5%, **= 1%, ***= 1‰

Among the negative relationships, shell thickness-good kernel ratio (35.1%), shell thickness-kernel size (30.4%) and shriveled kernel ratio-good kernel ratio (29.2%) relationships were found to be significant.

The highest positive relationships were between nut size-kernel weight (83.5%), nut weight-kernel weight (80.7%), average blanching rate-full blanching rate (78.6%), nut weight-nut size (79.0%), nut size-kernel size (76.2%), kernel weight-kernel size (65.5%), kernel weight-kernel percentage (63.7%), nut weight-kernel size (52.0%), kernel weight-kernel cavity (45.7), shell thickeness-shriveled kernel ratio (45.0%), nut size-kernel cavity (44.1%), kernel weight-kernel percentage (43.3%), nut weight-kernel cavity (41.5%), good kernel ratio-kernel percentage (40.7%), nut size-kernel percentage (38.0%), kernel size-kernel cavity (34.7%) and kernel weight-good kernel ratio (30.4%), respectively.

4. Discussion

The results of this study could not be directly compared with the results of previous research, as no study revealing the relationships between the quality characteristics of hazelnuts harvested according to different methods could be found. For this reason, the correlation analysis results of previous studies on the examined features were included in the evaluation.

In our study, in two groups of samples, the relationships of nut size, kernel weight, kernel size and kernel cavity with nut weight were positively significant. The relationship between nut weight and shell thickness was found to be insignificant. In previous studies, nut weight-nut size, nut weight-shell thickness, nut weight-kernel weight and nut weight-kernel size relationships were positive and significant in Tombul and Kalınkara varieties (Bostan, 1995); the nut weight-shell thickness relationship was positive and significant in Tombul, Palaz, Sivri and Kalınkara varieties (Bostan, 1999a); in Palaz and Sivri varieties, nut weight-nut size, nut weight-kernel size and nut weight-shell thickness relationships were positive and significant (Bostan and İslam, 1999b); nut weight-nut size and nut weight-kernel weight relationships were positive in hazelnut genotypes (Yao and Mehlenbacher, 2000); in the Tombul variety, nut weight-kernel weight and nut weight-kernel cavity relationships were positive, significant, the others were insignificant (Bostan, 2003); nut weight-nut size, nut weight-kernel size and nut weight-kernel weight relationships were positive in hazelnut genotypes (Sharma, 2003); in Tombul, only the nut weight-kernel weight relationship was positive and significant, the others were insignificant (Karadeniz and Bostan, 2004); in Tombul, Palaz, Çakıldak and Kalınkara varieties, nut weight-nut size, nut weight-shell thickness, nut weight-kernel weight and nut weight-kernel cavity relationships were positive and significant (İslam et al., 2005); in Tombul variety, nut weight-kernel weight, nut weight-nut size and nut weight-kernel size relationships were positive and nut weight-shell thickness relationship was negatively significant.

In Kalınkara variety, nut weight-kernel weight and nut weight-kernel size relationships were positive and nut weight-shell thickness relationship was negatively significant. In Sivri variety, nut weight-kernel weight relationship was positively significant (Akdemir, 2010); in Palaz and Tombul varieties, nut weight-kernel weight relationships were positively significant, nut weight-shell thickness and nut weight-kernel cavity relationships were negatively significant (Bak, 2010); in the Tombul variety, the nut weight-kernel weight relationship was positively significant and the nut weight-shell thickness relationship was negatively significant (Kırca, 2010); nut weight-nut size relationship was positively significant in 10 hazelnut varieties (Milošević and Milošević, 2012); nut weight-kernel weight relationship was positively significant in the hazelnut population (Mohammadzedeh et al., 2014); in the wild hazelnut population, nut weight-nut size, nut weight-kernel weight and nut weight-kernel size relationships were positively significant (Ershadi et al., 2020); in Tombul and Palaz varieties, nut weight-kernel weight and nut weight-kernel cavity relationships were positively significant, nut weight-nut size, nut weight-shell thickness and nut weight-kernel size relationships were insignificant (İşbakan and Bostan, 2020); in the Çakıldak variety, nut weight-nut size, nut weight-shell thickness, nut weight-kernel weight and nut weight-kernel size relationships were found to be positively significant (Top and Bostan, 2020); in Tombul and Palaz varieties, nut weight-kernel weight relationships were found to be positive, nut weight-kernel cavity and nut weight-shell thickness relationships were found to be negatively significant (Bak and Karadeniz, 2021). The study results were largely similar in terms of the positive relationships between nut weight-nut size, nut weight-kernel weight and nut weight-kernel size.

In this study, while the relationships between the kernel percentage and nut weight, shell thickness and kernel cavity were insignificant in both groups of samples, the kernel percentage-kernel weight relationship and also the kernel percentage and nut and kernel sizes in the samples collected from the ground were found to be positively significant. In previous studies, kernel percentage was highly and negatively related to nut weight (Mehlenbacher et al., 1993); kernel percentage-nut weight and kernel percentage-shell thickness relationships in Tombul variety and kernel percentage-shell thickness relationship in Kalınkara were negatively significant and kernel percentage-kernel weight relationship was insignificant in Tombul and positive significant in Kalınkara (Bostan, 1995); kernel percentage-nut size and kernel percentage-shell thickness relationships were negative in Palaz and Sivri varieties, kernel percentage-kernel weight relationship was insignificant in Palaz, positive in Sivri, kernel percentage-nut weight relationship was negative in Palaz and insignificant in Sivri (Bostan and İslam, 1999b); in hazelnut genotypes, kernel percentage-nut size and kernel percentage-nut weight relationships were negatively significant (Yao and Mehlenbacher, 2000); in the Tombul variety, kernel percentage-kernel weight and kernel percentage-kernel size relationships were positively significant, while kernel percentage-nut weight, kernel percentage-shell thickness and kernel percentage-kernel cavity relationships were insignificant (Bostan, 2003); in hazelnut genotypes, kernel percentage-nut size, kernel percentage-kernel size and kernel percentage-nut weight relationships were negatively related, while kernel percentage-kernel weight relationship is positively related (Sharma, 2003); in the Tombul variety, the kernel percentage-kernel weight relationship was positively significant and the kernel percentage-nut weight, kernel percentage-nut size, kernel percentage-shell thickness, kernel percentage-kernel size and kernel percentage-kernel cavity relationships were insignificant (Karadeniz and Bostan, 2004); in hazelnuts, kernel percentage-shell thickness and kernel percentage-nut weight relationships were negatively significant (Valentini et al., 2004). In Tombul, Palaz, Çakıldak and Kalınkara varieties, there were negative significance relationships between the kernel percentage and nut size, nut weight, shell thickness, kernel cavity, and there was an insignificant relationship between the kernel percentage-kernel weight (İslam et al., 2005). In Tombul variety, kernel percentage-kernel weight and kernel percentage- kernel weight relationships were positive, in Kalınkara variety, kernel percentage-nut weight relationship was positive and kernel percentage-shell thickness relationship was negatively significant, in Sivri variety, kernel percentage-nut weight and kernel percentage-kernel weight relationships were positively significant (Akdemir, 2010); the kernel percentage-nut weight relationship was positive and significant in the Palaz variety, but insignificant in the Tombul variety (Bak, 2010); in the Tombul variety, kernel percentage-nut weight and kernel percentage-kernel weight relationships were positively significant, while kernel percentage-shell thickness relationship was negatively significant (Kırca, 2010); The kernel percentage-nut weight relationship was positive and significant in the hazelnut population (Mohammadzedeh et al., 2014); the kernel percentage-nut weight relationship was insignificant in Tombul and Palaz varieties (İşbakan and Bostan, 2020); in the Çakıldak variety, the kernel percentage-nut weight relationship was insignificant (Top and Bostan, 2020); In the Palaz variety, kernel percentage-nut weight and kernel percentage-kernel weight relationships were found to be positively significant (Bak and Karadeniz, 2021). The positive relationship between kernel percentage and kernel weight was similar in almost all previous studies.

Hazelnut varieties with large fruits have higher rates of abortive and shriveled kernels (Mehlenbacher, 1991; Thompson et al., 1996); it has also been stated that shriveling was a genetic feature and that this may be related to cell size or composition (Thompson et al., 1996). On the other hand, it has been stated that the heritability of good kernel ratio in hazelnuts was medium (42%), shriveled kernel ratio is low (22%), and there was a negative relationship between good kernel ratio and shriveled kernel ratio (Mehlenbacher et al., 1993). In our study, this relationship was negative in both sample groups, but significant only in samples collected from the ground, while İşbakan and Bostan (2020) also stated that the relationship between good kernel ratio and defective kernel ratio was negatively significant. On the other hand, the relationship between good kernel ratio and kernel percentage, which was insignificant in samples collected from the branch, was found to be positively significant in samples collected from the ground, and it was stated that this relationship was insignificant in the Tombul variety (Bostan, 2003). In the samples collected from the ground, the relationship between good kernel ratio and shriveled kernel ratio was found to be negatively significant. As in our study, Karadeniz and Bostan (2004) found the good kernel ratio-kernel percentage relationship to be positive and the good kernel ratio-shriveled kernel ratio relationship to be negatively significant. In our study, the good kernel ratio in samples collected from the branch was found to be positively related to nut-kernel weight and nut size, and the kernel weight and kernel percentage in samples collected from the ground. Ozturk et al. (2017) also found the relationships between the good kernel ratio and the kernel weight and kernel percentage to be positively significant, similar to our study. Bostan (2003) found the good kernel ratio-shell thickness relationship to be positively significant in the Tombul variety. In our study, this relationship was found to be negative but insignificant in samples collected from the ground, similar to the previous study, and in samples collected from branches.

It was stated that the heritability of the blanching rate in hazelnuts was moderately high (48%) (Mehlenbacher and Smith, 1988), and that it varies significantly depending on varieties, ecology, years, temperature and duration of the blanching process (Köksal and Okay, 1997; Richardson and Ebrahem, 1997; Bostan, 1999b; Bostan and İslam, 1999a; Bostan and Günay, 2009). In our study, a positive significant relationship was determined only between the full and average blanching ratio in both sample groups, and the relationships between the blanching ratio and other fruit characteristics were insignificant. In previous studies, the blanching ratio was found to be negative with shell thickness in Tombul and Kalınkara varieties, positive with nut and kernel weight in Palaz variety, and negative with nut thickness in Sivri variety (Bostan and İslam, 1999c); in hazelnut genotypes, the blanching ratio was negative with nut and kernel weight and positive with nut size (Yao and Mehlenbacher, 2000); it has been stated that there was a positive relationship with hazelnut cultivars and the kernel rate in wild and local species (Frary et al., 2019). From these results, it is understood that the blanching ratio varies significantly under the influence of many factors.

5. Conclusions

As a result, it can be said that the hazelnut samples collected by hand from the ground were more homogeneous in terms of the quality characteristics examined than those collected from the branch; in the samples collected from the branch, quality characteristics were only significantly correlated with each other in a positive direction; quality characteristics interact more with each other in samples collected from the ground; in the samples collected from the ground, the shell thickness affects the good kernel ratio and the kernel size in the opposite direction, the shriveled kernel ratio was linearly affected, and in terms of other relations, there were generally no differences between the samples collected from the branch and the ground.

Compliance with Ethical Standards

Conflict of Interest

The authors declare that they have no conflict of interest.

Ethical approval

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Data availability

Not applicable.

Consent for publication

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