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ORIGINAL ARTICLE

# Long-term monitoring of dwarf eggs in clutches of Yellow-legged Gulls (*Larus michahellis*) breeding in a western Mediterranean colony

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**Abstract**

The present study provides data on clutches with dwarf eggs from a large sampling in a colony of Yellow-legged Gulls (*Larus michahellis*) over 31 years. Their occurrence was very low, with a global percentage of 0.26%. Significant variations were not detected among periods of 10 or 11 years. In all the cases, only one dwarf egg was found per clutch. Mean volume of dwarf eggs was 34% of that of non-dwarf eggs. Their content was mostly albumen and a very reduced quantity of yolk, and they were infertile. Several results of the study (the laying order of the dwarf eggs, their mean clutch size and the mean size of the non-dwarf eggs from clutches with dwarf eggs) support the hypotheses that runt eggs occur from a temporary disturbance to the reproductive tract.

**Keywords** Dwarf egg · Egg size · Clutch size · Yellow-legged Gull · *Larus michahellis*

**Zusammenfassung**

**Langzeitmonitoring von Zwergeiern in Gelegen von Mittelmeermöwen (*Larus michahellis*) in einer westmediterranen Brutkolonie**

Die vorliegende Studie liefert Daten über Gelege mit Zwergeiern aus einer großen Stichprobe in einer Kolonie von Mittelmeermöwen (*Larus michahellis*) über 31 Jahre. Ihr Vorkommen war mit einem Gesamtprozentsatz von 0,26% sehr gering. Zwischen den Zeiträumen von zehn oder elf Jahren wurden keine Schwankungen festgestellt. In allen Fällen wurde nur ein Zwergei pro Gelege gefunden. Das durchschnittliche Volumen der Zwergeier betrug 34% des Volumens von „normalen " Eier. Die Zwergeier bestanden hauptsächlich aus dem Eiweiß und einer geringen Dottermenge, und sie waren alle unfruchtbar. Mehrere Ergebnisse der Studie (die Legefolge der Zwergeier, durchschnittliche Gelegegröße und mittlere Größe der „normalen " Eier aus Gelegen mit Zwergeiern) unterstützen die Hypothese, dass Zwergeier durch eine vorübergehende Störung des Fortpflanzungstrakts entstehen.

## Introduction

The occasional presence of dwarf eggs has already been noticed since the early past century in some bird species, both in wild and poultry (Pearl and Curtis 1916; Bales 1919). Because of its unusual occurrence, citations on this type of eggs in wild birds are scarce and often are referred to chance finds (Ricklefs 1975; Cucco and Malacarne 1996; Dittmann and Hötker 2001; Svensson 2002). However, the research on clutches with these eggs requires large samples (that involve long-term monitoring) to be representative, precisely due to their low frequency of occurrence, and only a very few studies provide data from samples of this kind (e.g., Mallory et al. 2004; Swennen 2020). Furthermore, studies on these eggs do not take into account the characteristics of the remaining eggs in the clutch where they appear, which can provide information about the causes that produce them.

Gulls are a group of birds whose breeding biology has been traditionally more analysed, with many studies showing exhaustive descriptions of both clutch and egg parameters (e.g., Harris 1964; Haycock and Threlfall 1975; Baerends and Hogan-Warburg 1982; Kilpi 1990; Real et al. 2017).

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Although the occurrence of clutches with dwarf eggs in their colonies is also known since many decades ago (Leege 1911; Brouwer 1928), there are few references mentioning these eggs (Baerends and Hogan-Warburg 1982; Varela and De Juana 1986) or dealing specifically with them (Bahillo et al. 1991–1992; Eijkelenboom 2012), and the data they provide are usually scarce. Up to now, only two studies that focussed on dwarf eggs of breeding gulls provide data from large samples, which include many years of monitoring: Walters (1989) focussed on Black-headed Gulls (*Chroicocephalus ridibundus*) and Camphuysen (2020) on European Herring Gulls (*Larus argentatus*) and Lesser Black-backed Gulls (*L. fuscus*). However, data on both the clutch size or remaining eggs of these unusual clutches are still lacking.

The aim of this study is to provide new data on clutches with dwarf eggs from a large sampling in a colony of Yellow-legged Gulls (*Larus michahellis*) over 31 years. It is intended to analyse the main descriptors of such clutches, including their percentage of occurrence, their mean size and the characteristics of both dwarf and non-dwarf eggs, to elucidate the possible causes of their production.

## Methods

The Medes Islands archipelago (42° 02′ 50″ N 3° 13′ 15.0″ E NE Spain) holds a large breeding colony of Yellow-legged Gulls that was subjected to annual culls between 1992 and 1996 (for a detailed description of the colony see Bosch and Sol 1998). Culling greatly affected the population dynamics and the dispersion of the colony since its implementation until many years later (Bosch et al. 2000, 2019).

Between the years 1992 and 2023, surveys of clutches were performed during the laying period (from mid-March to the end of April) of every breeding season in the colony to find clutches with dwarf eggs. The surveys included all the clutches laid both in several fixed plots for the monitoring of breeding parameters of the colony and in count strips mounted during the annual censuses of breeding pairs. When a dwarf egg was found, its length and width were measured using a calliper (nearest 0.1 mm), and its volume was estimated using the Harris equation (Harris 1964). Moreover, the size of the respective clutch was recorded; clutches smaller than three eggs were checked throughout the following days to ensure that they were completed. This allowed, at the same time, to determine the order of four dwarf eggs within some clutches. In 25 clutches with dwarf eggs, the length and width of the remaining eggs (i.e., 44 samples) were also recorded to determine their volumes. Since 1993 (when it was already certain that dwarf eggs are infertile), all dwarf eggs from completed clutches were removed and emptied to check their content. The annual percentage of occurrence of clutches with dwarf eggs was calculated in relation to the total number of clutches counted in the surveys. Variations in annual occurrences of clutches having dwarf eggs were tested by chi-squared test; data were grouped in three periods of 10 or 11 years (1992–2002, 2003–2012, and 2013–2023 excluding 2020) to ensure that expected frequencies were over five.

The size of the clutches with dwarf eggs was estimated from the sample of clutches found in the periodical surveys for the study of their occurrence plus seven of ten clutches found outside the surveys (in the remaining three, their clutch size could not be verified). Comparison of the frequency distribution of clutch sizes was tested using a contingency table. Following Koenig (1980), the cutoff between the size of dwarf eggs and that of normal eggs was expressed by a relationship between the mean ad the standard deviation. The mean size (length, width and volume) of the non-dwarf eggs belonging to the clutches with dwarf eggs was compared with that of eggs belonging to clutches without dwarf. Comparisons of the length as well as the volume were made using ANOVA and including the clutch as a factor, since data fitted to a normal distribution (length: K–S $d = 0.01$, $p = 0.150$; volume: K–S $d = 0.005$, $p = 0.968$); on the other hand, those of the width were made with the Mann–Whitney U test since the data did not fit a normal distribution (K–S $d = 0.02$, $p = 0.002$). No distinction was made between two- and three-egg clutches because of the low sample size of first ones containing a dwarf egg. Comparisons were performed including clutches laid throughout all the laying period, although no clutch with dwarf egg was found in the late laying period, when eggs are usually smaller (Mills 1979; Sydeman et al. 1991). To avoid possible biases, additional analyses were performed considering only three-egg clutches and excluding those of late laying period.

## Results

After checking 14,460 clutches, 27 of them contained dwarf eggs (0.26%). Between the years 1992 and 1994, other ten clutches with dwarf eggs were found in the colony but they were not included in the estimations of the percentages of occurrence as they were out of the surveys (chance fits). The annual percentages of occurrence of clutches with dwarf eggs ranged between 0.83% (year 1992) and lower than 0.16% (year 2008) (Fig. 1). In 15 breeding seasons, no clutch with dwarf eggs was recorded after checking in average more than 400 clutches per season. When considering the 10- or 11-year periods, occurrence frequencies did not vary significantly between them, ranging from 0.26 to 0.11% ($\chi^2_2 = 2.50$, $p = 0.287$).

All the clutches with dwarf eggs contained only one dwarf egg and the size of these clutches ranked between two

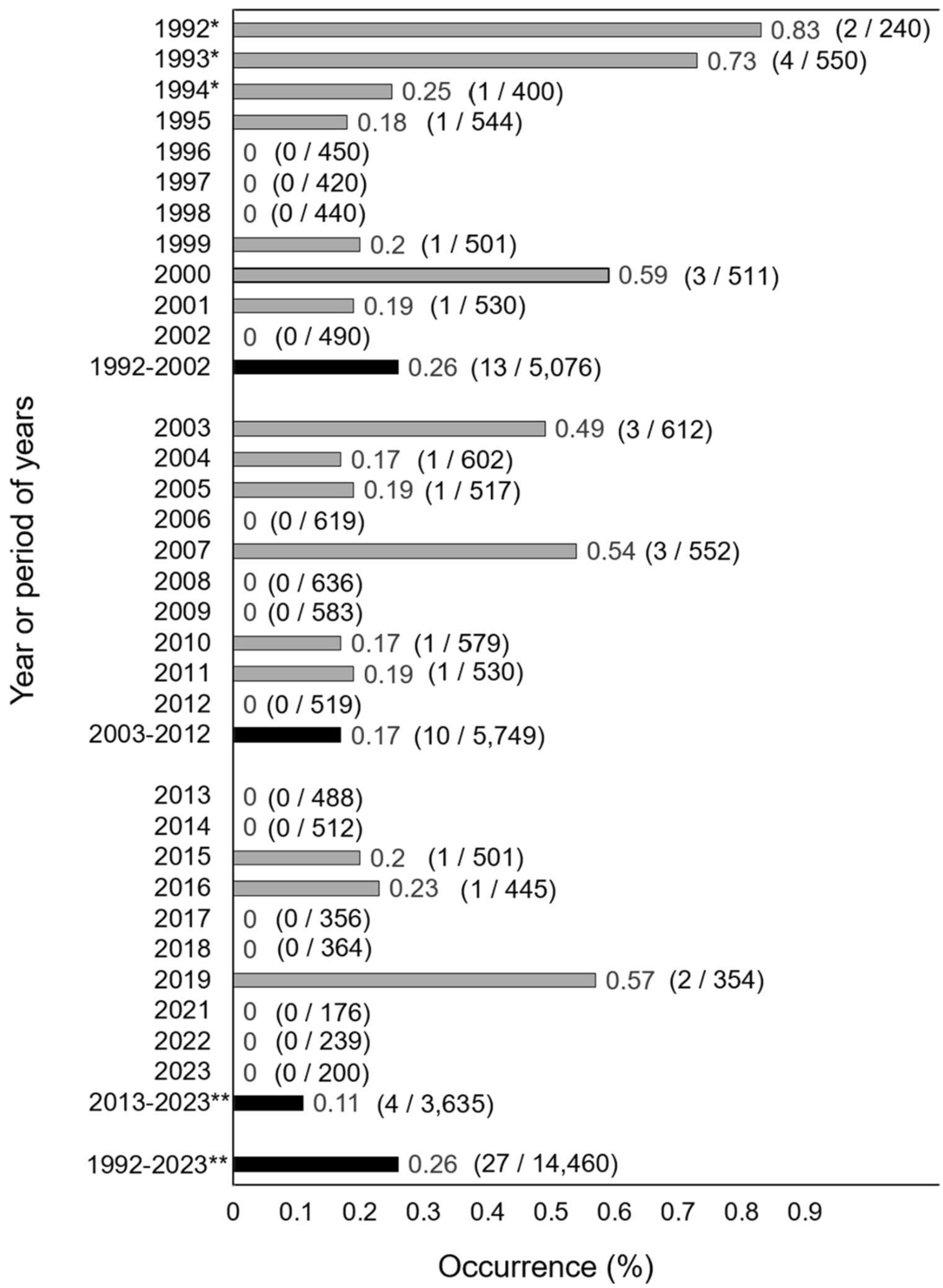



**Fig. 1** Occurrence of clutches of Yellow-legged Gulls with dwarf eggs in the Medes Islands colony over the 31 years of the study. Bars refer to relative frequencies in each year (grey) or in each period of years (black); next to each bar, the percentage value and, in brackets, both the total numbers of clutches with dwarf eggs and clutches sampled. *A total of ten clutches with dwarf eggs found between the years 1992 and 1994 are not included because they were not found in the periodical surveys. **Data do not include values of the year 2020 because government restrictions linked to Covid pandemic prevented sampling

and three eggs, so the remaining eggs were non-dwarf. Their mean clutch size was 2.85 eggs ± 0.36 (s.d.) ($n = 34$) and it did not differ significantly from that of clutches containing normal eggs, with 2.82 eggs ± 0.42 (s.d.) ($n = 2647$) ($\chi^2_1 = 0.09$, $p = 0.761$). All the clutches were laid between the onset and the peak of laying period.

The mean volume of dwarf eggs represented 34% of that of non-dwarf eggs. There was a difference of 11.47 mL between the largest volume value of a dwarf egg and the lowest of a non-dwarf egg (see Table 1). Such differences were more evident in the distribution of egg volumes according to their occurrence frequencies (Fig. 2), showing a cutoff between both egg types and are very low frequencies of eggs with volumes on either side of this cutoff. The cutoff was expressed as $D = \text{mean} - 5.01 \times \text{std. deviation}$. When considering length of eggs, differences were also so marked, but there was a very slight overlap of maximum value of dwarf eggs and minimum value of non-dwarf egg. This was due to an almost spherical non-dwarf egg, which had a very low length but a normal width, so its volume was larger than those of the dwarf eggs. The width of eggs also showed a very slight overlap of maximum value of dwarf

**Table 1** Size (mean ± standard deviation; range in square brackets) of the eggs of Yellow-legged Gulls breeding in the Medes Islands colony between 1992 and 2023 distinguishing among three different types of eggs: dwarf, non-dwarf within clutches containing dwarf eggs, and those of clutches without dwarf eggs. Data do not include values of the year 2020 because government restrictions linked to Covid pandemic prevented sampling

| Type of clutch | Type of egg | *n* | Length | Width | Volume |
|---|---|---|---|---|---|
| With dwarf egg | Dwarf egg | 37 | 45.86 ± 4.41 [36.38–53.95] | 35.31 ± 2.85 [27.68–41.52] | 27.73 ± 6.66 [13.27–43.75] |
| | Non-dwarf egg | 44 | 71.13 ± 3.07 [64.97–80.09] | 48.81 ± 1.81 [44.59–52.25] | 80.75 ± 6.84 [64.27–96.66] |
| Without dwarf egg | Non-dwarf egg | 7,458 | 70.28 ± 3.02 [53.02–82.11] | 48.89 ± 1.58 [41.31–53.93] | 80.12 ± 7.21 [55.22–107.66] |

eggs and minimum value of non-dwarf egg. This was due to two non-dwarf eggs with very elongated shapes due to their low widths but also with volumes larger than those of the dwarf eggs.

The mean size of the non-dwarf eggs belonging to the clutches with dwarf eggs was similar to that of eggs belonging to clutches without dwarf eggs (Table 1). Neither the width nor the volume varied significantly between both types of non-dwarf eggs, while the mean length was longer in the non-dwarf eggs from clutches with dwarf eggs (length: $F_{1,7263} = 3.94$, $p = 0.047$; width: $U = 161{,}788$, $Z = 0.160$, $p = 0.873$; volume: $F_{1,7263} = 0.94$, $p = 0.331$). When considering only non-late clutches of three eggs in additional analyses, results were similar (length: $F_{1,6417} = 3.99$, $p = 0.046$; width: $U = 121{,}818$, $Z = 0.249$, $p = 0.803$; volume: $F_{1,6417} = 0.68$, $p = 0.410$).

None of the emptied dwarf eggs showed any embryo development, not even those that had been removed a week after the other eggs of the clutch had hatched; they only contained albumen and a very reduced quantity of yolk.

Clutch order was known in only four out of the 32 dwarf egg clutches, and in all four cases the dwarf egg was the first-laid egg.

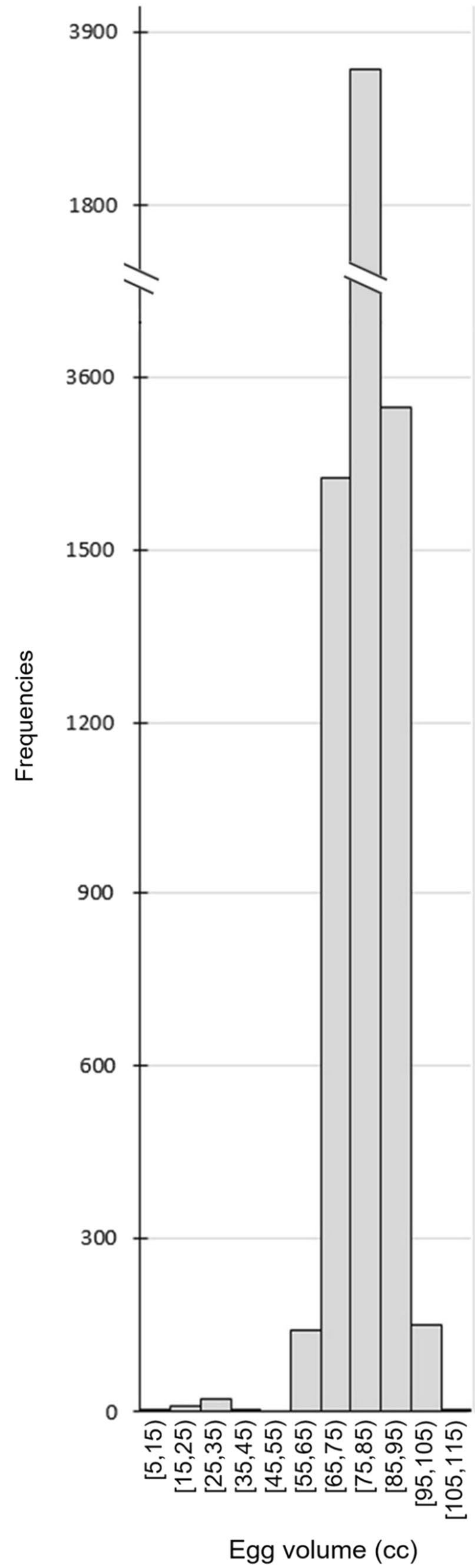
## Discussion

This is the first study that reports data on the occurrence frequency of clutches of Yellow-legged Gulls containing dwarf eggs, although existence of such clutches has been previously noticed for the species (Varela and De Juana 1986; Bahillo et al. 1991–1992). This occurrence was very low, with a global percentage of 0.26% after checking more than 14,000 clutches. Significant temporal variations were not detected when comparing periods of 10 or 11 years (values ranking between 0.11 and 0.26%), so it does not seem to have a great dependence on short- or medium-term environmental changes. The values found are similar to those calculated for Lesser Black-backed Gulls in a colony at Textel from data provided by Camphuysen (2020), with a 0.20% of clutches having a dwarf egg. The percentage calculated for European Herring Gulls from the data provided by Camphuysen (2020) in the same mixed colony was 1.40%, a value seven times larger than the previous one but which is also low. All these values imply that the probability of finding clutches with dwarf eggs in colonies that are not very large, at least in short-term sampling, is very low. This, in turn, could be the reason why there are virtually no papers on these clutches.

All the clutches with dwarf eggs found in the study contained only one dwarf egg per clutch. This result not only coincides with all the previous studies on gulls (e.g., Varela and De Juana 1986; Bahillo et al. 1991–1992; Eijkelenboom 2012; Camphuysen 2020) but also with most other bird species (Rookledge and Heald 1966; Rothstein 1973; Mulvihill 1987; Svensson 2002; Borgström 2004, 2005; Punta and Covazzi-Harriague 2020; however, see Swennen 2020). While a clutch is a fixed parameter, the number of eggs per clutch can vary largely not only among species but also among populations of the same species. For this reason, comparisons of the occurrence percentage between populations (of the same or different species) seem to be more suitable referred to the number of clutches than to the number of eggs checked, being the latter very variable depending on the size of the clutches checked. Nevertheless, most of the papers providing occurrence percentages refer to the eggs but not to the clutches checked.

Volume was the best external parameter to differentiate between dwarf and non-dwarf eggs, with a boundary higher of 11 mL between the highest value of a dwarf egg and the lowest value of a non-dwarf egg. This cutoff allowed to correctly classify the dwarf eggs of Yellow-legged Gulls reported in Varela and De Juana (1986) and Bahillo et al. (1991–1992) (in both cases, calculated from their lengths and widths) as well as those of European Herring Gulls reported in Brouwer (1928), Baerends and Hogan-Warburg (1982) and Camphuysen (2020) (in the last two cases, calculated from their lengths and widths) and those for Lesser Black-backed Gulls reported in Eijkelenboom (2012) and Camphuysen (2020). Dwarf eggs had a mean volume which represented 34% of that of non-dwarf eggs. When considering their content, they had mostly albumen and a very reduced quantity of yolk, and none of them had any embryo development. Therefore, they fit into the definition pointed by Koenig (1980) as eggs which are "abnormally" small and which do not hatch because of some internal abnormality.

**Fig. 2** Frequency distribution of the volume of Yellow-legged Gull ▶ eggs sampled in the Medes Islands colony between 1992 and 2023




The few clutches with dwarf eggs for which the laying order was known had the dwarf egg in the first position. Moreover, the few studies that provide data on the laying order of dwarf eggs do not show any tendency for these eggs to be laid in the last position (Kendeigh et al. 1956; Rookledge and Heald 1966; Mulvihill 1987); Crick (1995) pointed that such eggs appear at any stage in the laying sequence, reinforcing the idea of no specific tendency to be laid in the last position. On the other hand, the mean size of the clutches with dwarf eggs did not vary from that of the clutches without dwarf eggs. Moreover, the mean size of the non-dwarf eggs belonging to the clutches with dwarf eggs neither varied from that of eggs belonging to clutches without dwarf eggs. All of this leads to conclude that the small size of the dwarf eggs is not attributable to nutritional constraints, which would have involved both smaller clutch size or smaller non-dwarf eggs or the lowest egg being laid in the last position (Pierotti and Bellrose 1986; Hiom et al. 1991; Bolton et al. 1993; Kilpi et al. 1996; Real et al. 2017). This is supported by the fact that food available to the gulls of the colony has been described to be above the limiting threshold due to their large dependence on refuse tips, where they can find unlimited food (Bosch et al. 1994, 2000). The small size of dwarf eggs is neither attributable to the stimulus of the presence of previous eggs in the nest, which reduces the size of the third egg in the clutches of the gulls but not that of the two previous eggs (Parsons 1976). On the other hand, none of the clutches with dwarf eggs were found at late breeding. In a similar way, Pearl and Curtis (1916) found that dwarf egg production is most likely to occur during the height of the breeding season, while Walters (1989) observed that such eggs were found equally spread over the laying period. Therefore, there is no clear tendency of dwarf eggs to be produced at the last breeding period. This, in addition to the fact that the size of the clutches and the non-dwarf eggs were not smaller than the average values, suggests that they were probably not laid by young gulls, which tend to breed late and have smaller eggs and/or clutches (Mills 1979; Sydeman et al. 1991). This is reinforced by the fact that the production of dwarf eggs is not associated with immaturity of the sex organs (Pearl and Curtis 1916), which would be expected to occur in younger breeding gulls. The results of the present study are consistent with previous hypotheses that runt eggs occur from a temporary disturbance to the reproductive tract and it may affect any bird (Pearl and Curtis 1916; Mallory et al. 2004; Camphuysen 2020).

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s10336-024-02179-8.

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## Declarations

**Ethical statement** All sampling carried out in this study complies with current Spanish and Catalan laws and has permission of the regional wildlife authority government (Generalitat de Catalunya); no approval of research ethics committees was required to accomplish the goals of this study.



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