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# Assessment of heavy metal levels and fatty acid compositions of some krill oil capsules marketed in Turkey

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## Abstract

Krill oil has many positive health effects since it is rich in omega-3, phospholipids and astaxanthin. In recent years, as a result of rapid population growth and industrialization, the toxic heavy metal levels have increased especially in aquatic environments. Therefore, it is also possible to take up heavy metals to the human body through food supplements such as krill oil. This study aims to determine the fatty acid composition and the amounts of lead, mercury and cadmium in five different krill oil capsules. A total of 35 fatty acids were analysed. It was determined that the five different krill oil capsules met a proportion of daily recommended omega-3 fatty acid (EPA + DHA) and omega-6 fatty acid intake. Mercury levels were <0.2 µg/kg, cadmium levels <3 µg/kg and lead levels <3 µg/kg in all samples. It was observed that the heavy metal amount was below the limits specified by the Turkish Food Codex Contaminants Regulation. Based on the evaluation of the data obtained from our study, reliable krill oil capsules may be recommended for those who consume less than the recommended daily intake of omega-3 fatty acids, and for the vegetarians.

**Keywords:** Heavy metal, Krill oil, Omega-3, Omega-6, Fatty acid

## Introduction

"Krill" is the general name given to the small crustaceans in the order Euphausiacea and means "young fish" in Norwegian. Krills are shrimp-like marine species usually found in cold oceans, feeding on planktons and algae. Although it is generally used in aquaculture, sport fishing and used as fish feed, interest in krill has increased recently due to its positive health effects. Krill contains essential fatty acids such as α-linolenic acid (18:3, ω-3) and linoleic acid (18:2, ω-6). Also, while krill has a low level of saturated fatty acids and monounsaturated fatty acids (MUFAs), its polyunsaturated fatty acid (PUFA) content is high. Krill's fatty acid pattern is similar to that of shrimp and fish. However, while most fatty acids in fishes are in the form of triglycerides, 65% of the fatty acids in crustaceans are in the form of phospholipids (Tou, Jaczynski, & Chen, 2007).

Krill oil extracted from Euphausia superba Dana, 1850 (Euphausiacea), a key crustacean species in the Southern Ocean, has been used as a food supplement across the world since 2001 due to its high content of essential fatty acids. NASA has included krill oil in the nutrition program of astronauts since 2002 (Sanlıer & Bolukbası, 2016). Krill oil has many positive health effects since it is rich in omega-3, its lipid type is in the form of phospholipids (high water solubility) and it contains astaxanthin, an antioxidant (Tou et al., 2007).

Omega-3 fatty acids, which are polyunsaturated fatty acids, are metabolized in the human body as eicosapentaenoic acid (EPA; 20:5 ω-3) and docosahexaenoic acid (DHA; 22:6 ω-6). EPA and DHA are known to play an important role in the prevention or treatment of cardiovascular diseases, cancer, stroke and certain inflammatory diseases. Also, since DHA is an

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important component of the brain and retina, it is also crucial for brain development, learning ability and visual acuity (Calder, 2014). It has been shown that there is a positive correlation between low levels of DHA in brain cells and neurological diseases such as depression, memory loss, Alzheimer's disease and schizophrenia (Grosso et al., 2016; Hur et al., 2018; Joy, Mumby-Croft, & Joy, 2003). Since krill oil is rich in omega-3 fatty acids, many studies have been conducted considering its relationship with the abovementioned chronic diseases (Berge et al., 2015; Bunea, El Farrah, & Deutsch, 2004; Gamoh et al., 2011; Konagai et al., 2013; Lobraico et al., 2015). Krill oil shows significantly lower plasma lipid levels and improves endothelial function compared to fish oil and olive oil (Berge et al., 2015; Bunea et al., 2004; Lobraico et al., 2015). In addition, it has been reported that krill oil increases brain function and affects memory positively with its phospholipid content (Gamoh et al., 2011; Konagai et al., 2013). Krill oil is also effective in the prevention and treatment of some chronic diseases, as it is rich in astaxanthin, a powerful antioxidant, and neutralizes free radicals that cause cell damage. Astaxanthin also increases the resistance of krill oil to oxidation (Sanlıer & Bolukbası, 2016). As a result, the fact that krill oil is rich in EPA, DHA, phospholipids and anti-oxidants shows that it is suitable for human consumption.

In last several decades, the toxic heavy metal levels have rapidly increased especially in the aquatic environments as a result of rapid population growth and industrialization. Heavy metals have serious negative impacts on environment and life forms since they are used widely and do not undergo biological degradation. Organisms in the aquatic ecosystem accumulate these metals at higher rates in their bodies compared to their density in the water. The metals entering the food chain through this accumulation begin to create harmful effects as their amount increase in every level starting from the lowest level of the chain to the organism at the highest level (Tekeli, Yipel, & Sakin, 2016). Lead (Pb), mercury (Hg) and cadmium (Cd) are among the toxic heavy metals included in the top 10 dangerous substances specified by the Agency for Toxic Substances and Disease Registry ((ATSDR), 2019). Fish and other aquatic organisms living in the ecosystems contaminated by mercury, are the most important source of methyl mercury. Methyl mercury passes through the blood-brain barrier, placenta, and lactiferous ducts, and has toxic effects especially on liver, kidney, brain and immune system (Ozkan, Taslipinar, & Yesilkaya, 2018). Since the wastewater generated as a result of industrial activities is released to the streams, lakes, dams and seas without being treated, particularly Cd is taken by aquatic organisms and creates harmful toxic effects at different levels. High Cd intake can cause kidney diseases, osteoporosis, anemia, lung and prostate cancers in humans (Asri, Sonmez, & Citak, 2007; Türk Gıda Kodeksi Bulaşanlar Yönetmeliği, 2011). Lead is another heavy metal found in high amounts in aquatic organisms as a result of water contamination. Lead accumulates in the brain, lung, spleen, kidney cortex, erythrocytes, teeth, and mostly in the bones. Lead exposure in the fetal period may lead to mental retardation, movement disorder and kidney dysfunction. It may also cause a decrease in neurotransmitters such as acetylcholine, dopamine, and glutamate. Lead is also an endocrine disruptor that disrupts the synthesis, secretion and elimination of hormones in the body. Depending on Pb toxicity, disorders, behavior changes, attention deficit, comprehension difficulties and a decrease in school success can be observed in specific cognitive tests (Ozkan et al., 2018). The food supplements heading, for the first time, was added in the Turkish Food Codex Regulation on Contaminants issued in 2011 in Turkey, and the maximum limits were specified in line with the values of the European Union Directive EC 629/2008 (Türk Gıda Kodeksi Bulaşanlar Yönetmeliği, 2011). Accordingly, the maximum amount of Hg allowed in food supplements is 0.1 mg/kg and the amount of Pb is 3 mg/kg. The Cd limit was specified as 3 mg/kg for food supplements produced from dried seaweed, seaweed products or dried shelled molluscs, or those which contain these as their main components, and 1 mg/kg in others (Asri et al., 2007).

Here we investigate the fatty acid composition of five different krill oil capsules on the market and also determine the amounts of Pb, Hg and Cd they contained to find out whether these products are compatible with the maximum limits specified for the food supplements by the Turkish Food Codex Regulation on Contaminants.

## Materials and Methods

Within the scope of this research, five different brands of krill oil capsules which are used as food supplements and available in the market were sampled. Brands were kept confidential for ethical concerns and examples were named 1 - 2 - 3 - 4 - 5. The specified contents of krill oil samples used in the study are taken from the product leaflet and summarized in Table 1.

Table 1. Prospectus contents of krill oil samples

| Contents of samples | Sample1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 |
|---|---|---|---|---|---|
| Krill Oil (mg) | 500 | 700 | 500 | 500 | 500 |
| Phospholipids (mg) | 360 | 294 | 280 | 202 | 230 |
| Omega 3 (mg) | 260 | 175 | 145 | 86 | 135 |
| EPA (mg) | 125 | 102 | 85 | 40 | 72.5 |
| DHA (mg) | 62 | 60 | 45 | 25 | 44 |
| Choline (mg) | 76 | - | 35 | - | 28 |
| Astaxanthin (μg) | 200 | 70 | 50 | 101 | 640 (mg) |

Sampling was performed in a single run, 1-gram samples were taken from each product and placed in sample containers. To protect the samples from oxidizing, the sample containers were covered with aluminum foil. Krill oil samples were taken to Akdeniz University Food Safety and Agricultural Research Center to determine their fatty acid composition and heavy metal levels. Fatty acid composition analysis was done according to Ozogul et al. (Ozogul, Ozogul, & Alagoz, 2007). Accordingly, 2 M methanolic KOH and n-heptane were added to the krill oil samples to form methyl esters and analysis was performed using Gas Chromatography-Mass spectrometry (GC-MS Thermo Scientific, ISQ series).

**Results and Discussion**

A total of 35 fatty acids were analysed in five different brands of krill oil capsule samples. Of which 15 were saturated fatty acids (SFAs), 9 were monounsaturated fatty acids (MUFAs) and 11 were polyunsaturated fatty acids (PUFAs). The types and quantities of these fatty acids were presented in Table 2. The highest level of SFA and MUFA was in the sample 5 (67.048 g/100g and 16.800 g/100g, respectively) and the highest level of PUFA was in the sample 1 (20.494 g/100g). The lowest level of SFA and MUFA was in sample 1 (64.297 g/100g and 15.209 g/100g respectively), while the lowest level of PUFA was in sample 5 (15.579 g/100g). When the krill oil samples were analysed for their EPA and DHA contents, the following results were observed. The highest EPA content was found in sample 3 (10.870 g/100g), the lowest EPA content in sample 2 (7.877 g/100g); the highest DHA content in sample 1 (3.054 g/100g), and the lowest DHA content in sample 5 (1.693 g/100g).

Figure 1 represents comparison of EPA; DHA; EPA+ DHA, omega-3 (ω-3), omega-6 (ω-6) fatty acid amounts obtained from krill oil capsule samples. It was observed that the highest ω-3 level and the lowest ω-6 content were in sample 3; the highest ω-6 level was in sample 1 and the lowest ω-3 content was in sample 2.

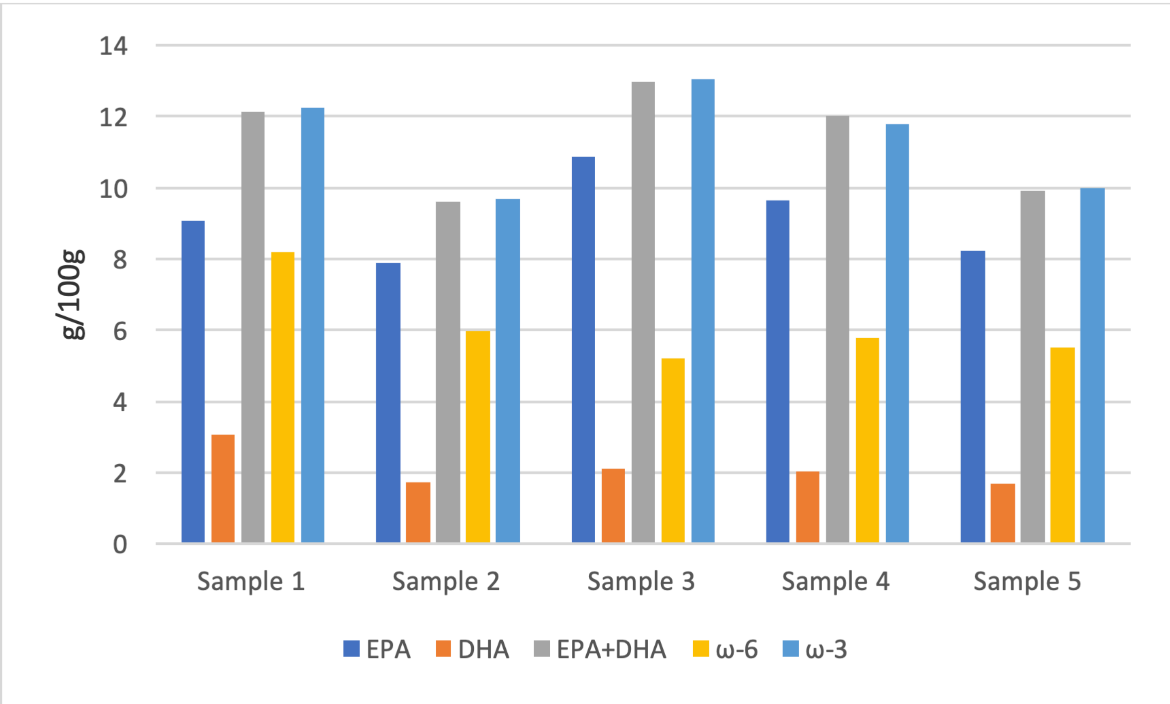


Figure 1. Comparison of EPA, DHA, ω-3 and ω-6 levels of krill oil capsules

Table 2. Fatty acids composition in the samples of krill oil capsules

| Fatty Acids | (g/100g) | | | | |
|---|---|---|---|---|---|
| **Saturated Fatty Acid (SFA)** | **Sample 1** | **Sample 2** | **Sample 3** | **Sample 4** | **Sample 5** |
| C8:0 Caprylic acid | N.F.D.L | N.F.D.L | N.F.D.L. | N.F.D.L | N.F.D.L |
| C10:0 Capric acid | 0.546 | N.F.D.L | 0.212 | N.F.D.L | N.F.D.L |
| C11:0 Undecanoic acid | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L |
| C12:0 Lauric acid | 0.159 | 0.131 | 0.135 | 0.088 | 0.123 |
| C13:0 Tridecanoic acid | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L |
| C14:0 Myristic acid | 13.734 | 19.141 | 16.653 | 17.067 | 18.357 |
| C15:0 Pentadecanoic acid | 0.531 | 0.365 | 0.329 | 0.495 | 0.506 |
| C16:0 Palmitic acid | 44.586 | 44.320 | 44.375 | 45.791 | 45.141 |
| C17:0 Heptadecanoic acid | 0.237 | 0.095 | 0.090 | 0.140 | 0.087 |
| C18:0 Stearic acid | 4.324 | 3.599 | 4.065 | 3.301 | 3.242 |
| C20:0 Arachidic acid | 0.098 | 0.087 | 0.073 | 0.085 | 0.082 |
| C22:0 Henicosanoic acid | 0.017 | 0.009 | 0.008 | 0.011 | 0.012 |
| C22:0 Behenic acid | 0.066 | 0.044 | 0.058 | 0.070 | 0.072 |
| C23:0 Tricosanoic acid | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L |
| C24:0 Lignoceric acid | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L |
| **ΣSFA** | **64.297** | **67.790** | **65.996** | **67.048** | **67.621** |
| **Monounsaturated Fatty Acids (MUFA)** | | | | | |
| C14:1 Myristoleic acid | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L |
| C15:1 cis-10-Pentadecenoic acid | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L |
| C16:1 Palmitoleic acid | 2.910 | 4.672 | 5.283 | 5.401 | 6.631 |
| C17:1 cis-10-Heptadecenoic acid | N.F.D.L | N.F.D.L. | N.F.D.L | N.F.D.L | N.F.D.L |
| C18:1n9c Oleic acid | 11.895 | 11.314 | 9.954 | 9.396 | 9.701 |
| C18:1n9t Elaidic acid | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L |
| C20:1n9 cis-11-Eicosenoic acid | 0.199 | 0.238 | 0.184 | 0.204 | 0.222 |
| C22:1n9 Erucic acid | 0.204 | 0.333 | 0.254 | 0.279 | 0.246 |
| C24:1n9 Nervonic acid | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L |
| **ΣMUFA** | **15.209** | **16.558** | **15.675** | **15.279** | **16.800** |
| **Polyunsaturated Fatty Acids (PUFA)** | | | | | |
| C18:2n6c Linoleic acid | 3.280 | 2.162 | 1.846 | 2.340 | 2.227 |
| C18:2n6t Linolelaidic acid | 1.845 | 1.751 | 1.594 | 1.688 | 1.655 |
| C18:3n3 γ-Linolenic acid | 0.130 | 0.069 | 0.095 | 0.111 | 0.070 |
| C8:3n6 α-Linolenik asit | 3.000 | 1.972 | 1.714 | 1.709 | 1.601 |
| C20:2 cis-11.14-Eicosadienoic acid | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L |
| C20:3n6 cis-8.11.14- Eicosatrienoic acid | 0.067 | 0.090 | 0.037 | 0.034 | 0.036 |
| C20:3n3 cis-11.14.17- Eicosatrienoic acid | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L |
| C20:4n6 Arachidonic acid | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L | N.F.D.L |
| C20:5n3 cis-5.8.11.14.17- Eicosapentaenoic acid | 9.061 | 7.877 | 10.870 | 9.661 | 8.216 |
| C22:2 cis.13.16-Docosadienoic acid | 0.058 | N.F.D.L | 0.083 | 0.098 | 0.080 |
| C22:6n3 cis-4.7.10.13.16.19- Docosahexaenoic acid | 3.054 | 1.732 | 2.090 | 2.031 | 1.693 |
| **ΣEPA** | **9.061** | **7.877** | **10.870** | **9.661** | **8.216** |
| **ΣDHA** | **3.054** | **1.732** | **2.090** | **2.031** | **1.693** |
| **ΣEPA+DHA** | **12.115** | **9.609** | **12.960** | **11.692** | **9.909** |
| **ΣPUFA** | **20.494** | **15.652** | **18.329** | **17.672** | **15.579** |

N.F.D.L; Not found in detectable level

The amount of heavy metal found in krill oil capsule samples are given in Table 3. The analyses revealed that the level of mercury was <0.2 μg/kg. the cadmium <3 μg/kg and lead <3 μg/kg in all samples.

Table 3. The amount of heavy metal in krill oil capsule samples solution

| Samples | Mercury (Hg) | Cadmium (Cd) | Lead (Pb) |
|---|---|---|---|
| **Sample 1** | <0.2 μg/kg | <3 μg/kg | <3 μg/kg |
| **Sample 2** | <0.2 μg/kg | <3 μg/kg | <3 μg/kg |
| **Sample 3** | <0.2 μg/kg | <3 μg/kg | <3 μg/kg |
| **Sample 4** | <0.2 μg/kg | <3 μg/kg | <3 μg/kg |
| **Sample 5** | <0.2 μg/kg | <3 μg/kg | <3 μg/kg |

Seafood has potential effects on health as it contains high-quality protein and minerals such as selenium and iodine, as well as high amounts of omega-3 fatty acids (Dahl, Mæland, & Bjørkkjær, 2011). While fatty fish (> 5% lipid) is considered as a good source of omega-3, the krill oil obtained from Euphausia superba is stated to be a good source of long-chain omega-3 fatty acids (Adıguzel, Isgin, & Pekcan, 2015; Dahl et al., 2011). There are also vitamin A, vitamin E, phospholipids, and astaxanthin, an oil-soluble antioxidant carotenoid, in krill oil. Omega-3 fatty acids in krill oil are attached to phospholipids. Unlike triglycerides, phospholipids are amphiphilic and therefore their absorption is easier due to their emulsifying properties. This structural difference shows that krill oil provides better bioavailability and oxidative stability than oils extracted from other seafoods (Adıguzel et al., 2015; Lu, Bruheim, Haugsgjerd, & Jacobsen, 2014). It has been reported that krill oil has antithrombotic, antiarrhythmic, antiatherosclerotic and anti-inflammatory effects due to its rich EPA, DHA and anti-oxidant content (Ambati, Phang, Ravi, & Aswathanarayana, 2014; Calder, 2015; Casula, Soranna, Catapano, & Corrao, 2013).

The Food and Agriculture Organization of the United Nations recommends at least 250 mg/day EPA and DHA intake for male adults and non-pregnant/non-lactating females. It is emphasized that pregnant/lactating females should take 300 mg/day EPA and DHA, at least 200 mg of which should be DHA (FAO, 2010). The European Food Safety Authority (EFSA) states that it is sufficient to take 250 mg/day EPA and DHA, and an additional 100-200 mg/day DHA in pregnancy (EFSA Panel on Dietetic Products, 2010). Although the toxic dose of krill oil is unknown, The United States Food and Drug Administration (FDA) has reported that over 3g/day omega-3 fatty acids consumption can lead to gastrointestinal problems such as bleeding, gas, bloating and diarrhoea, and that the therapeutic dose ranges from 1-3 g/day and it is appropriate to recommend 500 mg/day of it (Cunningham, 2012).

Evaluation of EPA and DHA content of krill oil samples investigated here showed that 100 g krill oil contained a minimum of 9.609 g and a maximum of 12.960 g EPA and DHA. The analysed samples were used in accordance with the EFSA's intake recommendations (250 mg/day) and they met EFSA's daily intake of EPA and DHA. The krill oil content in a single capsule of the analysed products varies between 500-700 mg and 1-2 capsule(s)/day intake is recommended.

Omega-3 and omega-6 fatty acids are essential fatty acids that are not synthesized in the human body and must be taken from external sources. While anti-aggregator, anti-inflammatory and vasodilating eicosanoids are synthesized from EPA and DHA, which are formed as a result of desaturation of omega-3 fatty acids, eicosanoids having the opposite effect are synthesized from arachidonic acid formed by omega-6 fatty acids. Currently, many chronic diseases are characterized by the overproduction of eicosanoids derived from omega-6 fatty acids. Therefore in order to protect health, it is essential to follow a balanced diet of omega-3 and omega-6 (Saini & Keum, 2018). Turkey Dietary Guidelines recommends a 1.6 g/day omega-3 and 17 g/day omega-6 intake for males between the ages of 19-50, and 1.6 g/day omega-3 and 14 g/day omega-6 for those between the ages of 51-65. A 1.1 g/day omega-3 and 12 g/day omega-6 intake is recommended for the females between the ages of 19-50, and 1.1 g/day omega-3 and 11 g/day omega-6 for those between the ages of 51-65. Therefore, at least 2-3 servings (approximately 300-500 g) of fish should be consumed per week to obtain the required fatty acids. Unfortunately, fish consumption is very low in Turkey, and 18.8% of the individuals living in the urban areas and 12.4% of the individuals living in the rural areas consume fish 1-2 times a week, according to the data obtained from Turkey Nutrition and Health Survey in 2010 (Guzelsoy & Izgi, 2015).

The data obtained here suggest that the highest n-3 content (13.055 g/100 g) and the lowest n-6 content (5.191 g/100 g) were in sample 3. On the other hand, the highest n-6 content (8.192 g/100 g) was in sample 1 while the lowest n-3 content (9.678 g/100 g) was in sample 2. Provided that all samples analysed were used in accordance with the FDA's intake recommendations (1-3 g), they met a portion of the daily intake of omega-3 and omega-6 recommended by the Dietary Guidelines for Turkey. The most important limitation of this study is that fatty acid analysis has not been repeated due to financial reasons.

In recent years, due to the rise of environmental and water pollution, the heavy metal levels (Cd, Pb, Hg) in the aquatic environment have increased dramatically. These heavy metals are accumulated in marine organisms, including fishes, through food chain. Therefore, these heavy metals may transmit to fish oils or krill oils as they are extracted from marine organisms. Here, it was determined that the heavy metals found in krill oil samples were below the maximum values specified for the food supplements by the Turkish Food Codex Regulation on Contaminants.

**Conclusion**

Based on the evaluation of the data obtained from our study, reliable krill oil capsules may be recommended for those who consume less than the recommended daily intake of omega-3 fatty acids, and for the vegetarians. However, considering the increase in the use of fish oils and other herbal/animal food supplements, it is thought that further studies should be carried out for their long-term use in terms of other contaminants and dosage values.

**Compliance with Ethical Standards**

**Conflict of interest**

The authors declare that for this article they have no actual, potential or perceived the conflict of interests.

**Author contribution**

The contribution of the authors is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

**Ethical approval**

Not applicable.

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**Data availability**

Not applicable.

**Consent for publication**

Not applicable.

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