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Morphological Study and Parametric Values of *Mesobuthus phillipsii* (Pocock, 1889) (Arachnida: Scorpiones: Buthidae) from Iran, Autumn 2023

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Abstract

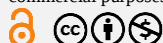
Background and Objective: The family Buthidae is the largest scorpion family, which, in addition to having a wide distribution worldwide, includes the most dangerous species. Scorpions of the genus *Mesobuthus* belong to the family Buthidae and are distributed throughout all regions of Iran, being the dominant species in most provinces. The present study was conducted in autumn 2023 to investigate the morphometric characteristics of *Mesobuthus phillipsii* in Rudan County, southern Iran.

Methods: A total of 40 adult male and female *M. phillipsii* scorpions (20 males and 20 females) were collected around the clock from the plain and mountainous areas. Then, the most important morphometric indices were measured using a graduated caliper. Finally, the collected data were analyzed using Excel. The Mann-Whitney test was used to compare the quantitative variable between the two groups (male and female). A P-value of <0.05 was considered to be statistically significant.

Findings: More than half of the morphometric indices were significantly different between male and female *M. phillipsii* scorpions. The sizes of various body parts were larger in female scorpions compared to their male counterparts (except for the length and number of teeth of the pectin organ). The number of pectin teeth was (20±1.41) in females and (25±0.06) in males. The number of pectin teeth, as one of the important sensory organs in scorpions, is used to distinguish between sexes and to identify species.

Conclusion: This study, focused on examining the morphometric traits of the scorpion species *M. phillipsii*, revealed that females exhibited higher average values for most measured morphometric characteristics compared to males, except for the number of pectin teeth, which did not differ significantly between the sexes.

Keywords: Scorpion, *Mesobuthus phillipsii*, Morphometry, Buthidae, Iran.



Introduction

The arthropod phylum represents some of the oldest living organisms in the natural evolutionary cycle on Earth, and scorpions are among the earliest animals to have appeared in the course of life's history (1). Scorpions belong to the largest group of arachnids and have long been feared and dreaded by humans due to their distinctive appearance and the presence of venom glands (2). They hold medical significance because of their venomous and potentially lethal sting. The venom apparatus is located at the end of the tail and consists of two venom glands, primarily used for capturing prey such as insects and for self-defense (3, 4). Scorpions are among the dangerous animals in the globe and have been able to adapt to their environment through physiological and behavioral adaptations for approximately 450 million years. These animals sting a large number of people annually, and dangerous species can cause human death within seven hours if medical treatment is not promptly available. Scorpion envenomation is a significant public health and medical issue in tropical and subtropical countries worldwide, threatening the lives of thousands of people each year. Today, it remains a health problem in southern Africa, western Asia, the southern United States (Mexico), and the Indian subcontinent. Approximately 1.2 billion people worldwide live in areas at risk of scorpion sting, with around one million cases of envenomation reported annually, resulting in a mortality rate of approximately 0.27%. Across Iran, especially in the warm and humid southern and southwestern regions, scorpion sting causes clinical complications and even fatalities (5).

To date, more than 2600 scorpion species (<https://www.ntnu.no/ub/scorpion-files/>) belonging to 21 families have been identified worldwide, of which the venom of about 20 species is dangerous and potentially lethal to humans. According to the latest reports, Iranian scorpions are classified into four families: Buthidae (C. L. Koch, 1837), which is the largest and most diverse family and the primary cause of medically significant scorpion stings in Iran; Hemiscorpiidae (Pocock, 1893), which includes the medically important genus *Hemiscorpius*, especially *Hemiscorpius lepturus*, a major cause of fatalities in southern Iran; Scorpionidae (Latreille, 1802), which is generally considered less medically significant than Buthidae; and Diplocentridae (Karsch, 1880), native to the New World except for the genus *Nebo* (Simon, 1878) found in the Middle East, characterized by a subaculear spine on the telson and not regarded as medically important. Overall, these families encompass 19 genera and 68 species in Iran (6,7). The family Buthidae is the largest family of scorpions, with a wide distribution worldwide, and includes the most dangerous species (8). In Iran, Buthidae is the most diverse scorpion family, comprising 44 species (9).

Scorpion species vary greatly in size, with adults ranging from 1 to 20 centimeters in length (10). Scorpions of the genus *Mesobuthus* (Vachon 1950) belong to the family Buthidae. These scorpions are distributed throughout all regions of Iran and are the dominant species in most provinces. Their size, coloration, and body pattern vary according to local forms in different areas, reaching a maximum length of about 6 centimeters. Their coloration ranges from translucent yellow to opaque and is usually uniform or accompanied by dark spots. *Mesobuthus* scorpions in Iran inhabit a wide range of environments, from lowlands to snow-covered highlands, and can be found under stones, rock fragments, beneath branches, and decayed leaves of trees. In Hormozgan Province, two species of this genus, namely, *Mesobuthus eupeus* (C.L. Koch, 1839) and *Mesobuthus phillipsii* (Pocock 1889) have been identified. These scorpions could be found across all counties of the province, from the low coastal plains to mountainous regions. Based on clinical observations and investigations, these scorpion species are considered low-risk, as no cases of severe complications or fatalities resulting from their sting have been reported to date (11). The only reason victims seek medical attention is due to pain, which ranges from moderate to severe following *Mesobuthus* envenomation. This pain typically resolves spontaneously within one to several hours without any further signs or symptoms (12).

Although these two species of scorpion are not considered highly dangerous or lethal compared to other medically important scorpions, their envenomation is reported more frequently due to their abundance. Therefore, it is regarded as a concern in terms of patient visits to healthcare centers (13). Existing information on the ecology and biology of scorpions is very limited, and enhancing this knowledge requires identification of their habitats as well as morphological and morphometric studies of scorpions in various regions of the country (2).

Since the advantage of using quantitative data over qualitative and descriptive data is a well-established principle in taxonomy (14), this study was conducted to examine the morphometric traits of *M. phillipsii* in southern Iran. Indeed, the value of describing a species increases through numerical data. Furthermore, the importance of quantitative data becomes even more apparent in relation to the concept of species instability and the existence of geographically variable populations. Such variation, it should be noted, cannot be adequately represented without quantitative data. This issue is particularly evident when two species or subspecies exhibit overlapping traits. Therefore, only by utilizing quantitative data from a sample population (with the aid of statistical methods) can accurate conclusions be drawn regarding the natural characteristics of the entire population (15). The present study aimed

to investigate the morphometric indices of *M. phillipsii* in Rudan County (27°32'N 57°15'E), Hormozgan Province (27°6'0" N, 56°0'0" E), southern Iran (autumn 2023).

Methods

Rudan County, situated approximately 190 meters above sea level and covering an area of about 30445 square kilometers, is located 100 kilometers east of Bandar Abbas County (the capital of Hormozgan Province). This county lacks cold winters and has a very hot and dry climate. It records the highest average annual temperature within the county and exhibits the highest temperature among all counties in the province. Due to the arid atmosphere, the relative humidity in this county is lowest compared to other counties in the province. The average annual precipitation is 250 millimeters, and the mean temperature ranges between 27 and 28 degrees Celsius.

This descriptive study was done using the random capture method for collecting scorpions from mountainous and plain areas both during the nighttime and daytime. Various collection techniques were employed, including rock rolling, UV light, ordinary flashlight, pouring water into ground holes, and employing tools like long-handled forceps and gloves. The search to hunt scorpions was performed under stones, beneath tree branches, in abandoned places, livestock shelters, inside orchards, among construction debris, in courtyards, and inside homes. The collected specimens were preserved in 75% ethanol-filled containers with attached labels. Subsequently, identification was carried out in the laboratory of the Rudan County Health Network using valid identification keys including those by Farzanpey (1987) and Barahoei et al (2020), with the aid of a stereomicroscope to accurately determine the specimens' taxonomic positions. (6,9).

The most important biometric parameters of male and female *M. phillipsii*, including total body length, carapace length and width, mesosoma length, metasoma length, length and width of each of the first to fifth metasoma segments, telson length and width, pedipalp length, length and width of femur segment of the pedipalp, chela length, length and width of the patella of the pedipalp, length of the movable finger, length of the fixed finger, and the length and number of pectin teeth were measured using a calibrated caliper with a precision of 0.1 millimeter. Overall, the number of pectin teeth in males is greater than those in females. However, in many cases, the number of pectin teeth in males and females of a given species significantly overlaps. When the number of pectin teeth considerably overlaps between males and females, the sex of the scorpion can often be determined by the size of the pectins themselves. In many Buthi-

dae species, the males' pectins extend downward past the coxa-trochanter joint of the fourth leg, whereas in females, the tips of the pectins do not reach this joint.

M. phillipsii exhibit sexual dimorphism. Males tend to have more teeth on their pectines and a more slender, longer tail. Females, on the other hand, commonly have a wider, shorter tail. Males have more pectin teeth than females do. One study showed males with 21-25 while females possess 18-21 teeth. Another source noted higher counts, with males having 27-30 and females 22-26. The genital operculum is commonly not as wide or long in females, compared with males.

Inclusion criteria for the study were mature male and female scorpions, whereas immature and damaged specimens were excluded. All data were entered into IBM SPSS software/Singapore Pte Ltd, version 22.0. To analyze the difference between two groups (male and female) for a quantitative variable, the nonparametric equivalent test, Mann Whitney, was used. A P-value of <0.05 was considered to be statistically significant. The location of Rudan County and scorpion collection sites are indicated in Figure 1.

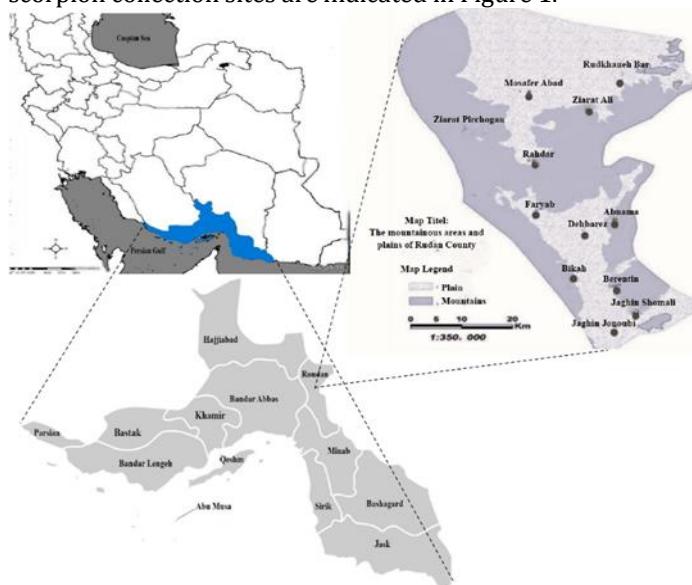


Figure 1: Location of Rudan County in Hormozgan Province, southern Iran, mountainous and plain areas and scorpion collection sites in Rudan County.

Results

In the present study, the collected specimens of *M. phillipsii* (Figures 2,3,4) exhibited coloration ranging from yellow to dark yellow. The ventral surfaces of the metasoma segments lacked rows of elongated denticles, whereas the margins of the fifth metasoma segment were well-developed and featured regularly arranged denticles. Sexual dimorphism within *M. phillipsii* was determined based on pectin organ length and the count of pectin teeth. The pectin teeth length and number in males were measured at $5.85 \pm$

0.15 mm, with a range of 23 to 27 teeth, whereas in females these measurements were 5.35 ± 0.15 mm, with 18 to 22 teeth.

A total of 40 adult specimens (20 males and 20 females) were subjected to morphometric analysis using a vernier caliper with a precision of 0.1 mm. The resulting morphometric data are summarized in Table 1. Analysis revealed that females exhibited signifi-

cantly larger overall body sizes compared to males. Parameters such as pecten length and pecten teeth count demonstrated statistically significant sexual dimorphism, with females showing lower indices than males in these parameters. Conversely, other morphometric characters were either larger or approximately equivalent in size in females relative to males. The scorpion species caught in this study are listed in Table 2.



(A)

(B)

Figure 2: *Mesobuthus phillipsii* : A) Ventral view; B) Dorsal view



Figure 3: Metasoma of *Mesobuthus phillipsii* : Has a hairy metasoma, with long and often dense seta.

Figure 4: Prosoma and Mesosoma of *Mesobuthus phillipsii*: Left (male) Right (Female)

Table 1: Results of measurements of important morphometric indices of male and female *Mesobuthus philipsii* scorpion specimens, Rudan County, southern Iran, Autumn 2023

Dimensions(mm)	Description	Total	X(mm)♂	±SD	Total	X(mm)♀	±SD	P
Carapace	L Carapace Length	20	4.01	0.27	20	4.90	0.20	0.05*
	W Carapace Width	20	3.90	0.22	20	4.69	0.29	0.001*
Mesosoma	L Mesosoma Length	20	12.0	0.98	20	15.92	1.16	0.001*
Metasoma	L Metasoma Length	20	23.30	1.25	20	26.24	1.13	0.001*
Segment I	L Segment I Metasoma Length	20	2.98	0.16	20	3.00	0.17	0.62
	W Segment I Metasoma Width	20	3.00	0.28	20	3.30	0.14	0.6
Segment II	L Segment II Metasoma Length	20	3.50	0.33	20	3.80	0.13	0.43
	W Segment II Metasoma Width	20	2.95	0.40	20	3.24	0.11	0.04*
Segment III	L Segment III Metasoma Length	20	3.60	0.43	20	3.90	0.13	0.12
	W Segment III Metasoma Width	20	3.00	0.44	20	3.28	0.11	0.35
Segment IV	L Segment IV Metasoma Length	20	4.18	0.24	20	4.50	0.11	0.02*
	W Segment IV Metasoma Width	20	2.75	0.17	20	3.00	0.14	0.05
Segment V	L Segment V Metasoma Length	20	4.80	0.38	20	5.30	0.14	0.03*
	W Segment V Metasoma Width	20	2.40	0.26	20	2.51	0.12	0.65
Telson	L Telson Length	20	3.90	0.08	20	4.90	0.12	0.02*
	W Telson width	20	1.80	0.08	20	2.30	0.10	0.02*
Pedipalp	L Pedipalp Length	20	7.00	0.36	20	8.12	0.25	0.01*
Manus	L Manus Length	20	1.50	0.10	20	1.80	0.10	0.02*
	W Manus Width	20	0.39	0.08	20	0.38	0.04	0.56
Femur	L Femur Length in Pedipalp	20	4.32	0.35	20	4.45	0.15	0.02*
	W Femur Width in Pedipalp	20	0.85	0.05	20	1.00	0.10	0.3
Patella	L Patella Length in Pedipalp	20	3.40	0.30	20	4.00	0.10	0.04*
	W Patella Width in Pedipalp	20	1.00	0.09	20	1.09	0.08	0.2
Chela	L Chela Length in Pedipalp	20	3.40	0.23	20	3.87	0.13	0.02*
Movable Finger	L Movable Finger Length	20	1.88	0.12	20	2.06	0.12	0.03*
Fixed Finger	L Fixed Finger Length	20	1.75	0.13	20	1.95	0.09	0.02*
Pectin	L Pectin Length	20	5.85	0.15	20	5.35	0.15	0.05*
Number of Pectin teeth	N Number of Pectin teeth	20	25.0	0.06	20	20.0	1.41	0.001*
Length of Body	L Length of Body	20	50.2	0.22	20	60.1	1.16	0.001*

*:The difference was statistically significant

Table 2: Scorpion species collected in Rudan County, southern Iran, Autumn 2023

Collection site	Topography	Height above sea Level (m)	Longitude and latitude	Species
Ziaratali	Mountain	498	27° 44' 35.87" N, 57° 13' 57.55" E	<i>Hemiscorpius acanthocercus</i> , <i>Odonthobuthus doriae</i> , <i>Androctonus crassicauda</i> , <i>Mesobuthus phillipsii</i> , <i>Mesobuthus persicus</i>
Rokhanehbar	Mountain	498	27° 49' 45.64" N, 57° 17' 41.69" E	<i>H. acanthocercus</i> , <i>Hemiscorpius enischnochela</i> , <i>O. doriae</i> , <i>M. phillipsii</i> , <i>M. persicus</i>
Rahdar	Mountain	591	27° 36' 58.97" N, 57° 6' 3.83" E	<i>A. crassicauda</i> , <i>M. phillipsii</i> , <i>O. doriae</i>
Faryab	Mountain	325	27° 28' 10.96" N, 57° 4' 16.30" E	<i>A. crassicauda</i> , <i>H. acanthocercus</i> , <i>M. phillipsii</i> , <i>M. persicus</i> , <i>Hottentotta schach</i>

Brantin	Mountain	184	27° 17' 44.99" N, 57° 14' 59.51" E	<i>A. crassicauda</i> , <i>M. phillipsii</i>
Abnama	Mountain	218	27° 27' 37.66" N, 57° 15' 21.14" E	<i>A. crassicauda</i> , <i>M. phillipsii</i> , <i>M. persicus</i>
Dehbarz	Plain	190	27°25'40"N, 57°12'6"E	<i>A. crassicauda</i> , <i>M. phillipsii</i> , <i>Mesobuthus kermanensis</i>
Bikah	Plain	180	27° 21' 17.60" N, 57° 10' 20.95" E	<i>A. crassicauda</i> , <i>M. phillipsii</i> , <i>Mesobuthus mirshamsii</i>
Jeghin Shomali	Plain	234	27° 13' 28.48" N, 57° 22' 38.44" E	<i>A. crassicauda</i> , <i>M. phillipsii</i> , <i>M. persicus</i>
Jeghin Jonobi	Plain	212	27° 12' 17.99" N, 57° 20' 41.33" E	<i>A. crassicauda</i> , <i>M. phillipsii</i> , <i>M. persicus</i> , <i>O. doriae</i>
Mosaferabad	Plain	534	27° 52' 54.94" N, 57° 11' 51.87" E	<i>A. crassicauda</i> , <i>M. phillipsii</i>

Discussion

The first documented report of scorpions in Iran dates back to Olivier (1807) (14). Scorpion identification and determination of their relationships are conducted based on detailed analysis of morphological parameters and morphometric studies (15). Pocock in his 1889 article on the family Buthidae and the scorpions of the Natural History Museum of England, stated that within this family, the movable finger of the pedipalp possesses a row of 12 to 15 denticles, and three granules are present beneath the terminal denticle of the movable finger. Furthermore, the metasoma segments are smooth without smallpox-like depressions, and the carapace features carinae and is often granulated (16).

In the morphological study of *Iranobuthus kra-li* (Kovarik, 1997) in Fars Province (southern Iran), the measurements in millimeters for male and female specimens were, as follows: total body length 77.8 and 80.2, carapace length 8.62 and 8.5, mesosoma length 22.02 and 21, the first metasoma segment length 6.51 and 6.1, the second metasoma segment length 7.12 and 6.4, the third metasoma segment length 7.65 and 6.6, the fourth metasoma segment length 8.84 and 7.4, the fifth metasoma segment length 9.88 and 9.5, patella length in pedipalp 10.27 and 11, and telson length 8.5 and 8, respectively. All measured parameters in this species were smaller than those of the specimens in the present study and can be considered as distinguishing parameters for differentiating these two species (17).

In the morphometric study of male and female specimens of *Mesobuthus vesiculatus* (Pocock, 1899) collected from East Azerbaijan and West Azerbaijan (northwestern Iran), the following measurements in millimeters were recorded, respectively:

body length 61 and 59, pecten length 6.7 and 5.2, number of pecten teeth 26 and 20, telson length 5 and 6, patella length 6.7 and 6.2, maximum carapace length 6.2 and 6.1, length of the first metasoma segment 2.98 and 3, the second metasoma segment length 5.2 and 4.6, the third metasoma segment length 5.4 and 4.7, the fourth metasoma segment length 6 and 5.3, and the fifth metasoma segment length 6.7 and 6.3. Some of these morphometric characters values align with those of *M. phillipsii* in the present study, while others differ, which can serve as distinguishing characteristics for differentiating these two species (18).

In the faunistic study of Iranian scorpions, Mirshamsi et al. (2011) reported the number of pecten teeth in male and female populations of *Mesobuthus* species as ranging from 27 to 30 and 22 to 26, respectively. Additionally, the total body length of *M. phillipsii* was measured as 51.18 mm, carapace length as 5.38 mm, the distance from the fixed fingertip to the joint of the movable finger as 9.10 mm, and telson length as 6.36 mm, which correspond well with the results of the present study (19, 20).

In a study on scorpions from southeastern Anatolia, Turkey, Yağmur (2011) reported the number of pecten teeth in male and female *M. phillipsii* as ranging from 24 to 30 and 18 to 23, respectively, which is consistent with the results of the present study (21).

The results of Larti's thesis on the morphological characteristics of scorpions from Ramhormoz, Haftgel, and Gerash Counties (2016) showed that in *M. phillipsii*, the total body length was measured at 44.04 mm, carapace length at 4.96 mm, maximum length of the pedipalp forceps at 7.95 mm, and telson

length at 4.95 mm, which are generally consistent with the results of the present study (22).

Heddergott et al. (2016) conducted a morphometric diversity study of *M. eupeus mongolicus* in Mongolia by examining morphometric traits such as total body length, as well as the length and width of carapace, metasoma segments, chela, patella, and pedipalp femur in male and female populations from both highland and lowland collection sites. They found that the males collected from the two regions differed significantly in size, whereas the females exhibited similar morphometric characteristics (23).

The results of Fatemi et al.'s comparative morphometric study on *Odontobuthus bidentatus* (Lourenço and Pérezier 2002) and *Odontobuthus doriae* (Thorell, 1876) in Iran (2015–2016) demonstrated that species differentiation can be achieved through analysis of morphological traits (24). Accordingly, by studying the morphometric characteristics of *M. phillipsii* and the influence of climate on this species, it is possible to identify and characterize populations of this species.

The results of Ebrahimi et al.'s morphometric study on *M. eupeus* from Fars Province (2020), similar to the present study, showed that the size of different body parts in females are generally larger compared with males, with the exception that the number of pectin teeth in males (26.93 ± 0.88) is higher than that in females (22.02 ± 1.00) (25). Therefore, it can be concluded that *M. phillipsii* and *M. eupeus* do not differ significantly in their morphometric traits, and differentiation between these two species is based on other parameters such as the number and position of trichobothria, etc. Also, *M. phillipsii* is identified from *M. eupeus* by the following characters: dorsomedian carinae of pedipalp patella obvious; dorsal surface of pedipalp femur well granular; uniting posterior median and central carinae on the one or both sides of carapace; hairy metasoma segments and five longitudinal dark stripes on tergites (lacking in some specimens); pointed and short basal denticles of ventrolateral carinae of metasoma segments V; mildly developed ventral carinae on metasoma segments III and II with small granules; more narrower metasoma segments; short aculeus (26).

The relatively small number of collected specimens and the impossibility of collecting specimens from all areas of the county were the limitations of this study. The strengths of the research included, a large number of parameters measured in male and female specimens, sampling during day and night and by four methods. The highlight of this study was the rich fauna of scorpions in the region.

Conclusion

This study was conducted in autumn 2023 with the aim of investigating the morphometric characteristics of *M. phillipsii* in Rudan County, southern Iran. The results demonstrated that the species exhibits sexual dimorphism in its adult form. Specifically, female scorpions have, on average, larger body sizes compared to males. Parameters such as pectin length and the number of pectin teeth showed significant differences between males and females; however, other measured characteristics were larger (or approximately similar) in females compared to males. Given the data obtained and the wide distribution of this species in the southern regions of the country, along with the limited ecological and biological information available, it is evident that identifying this species is crucial for the development of effective scorpion sting prevention programs.

Footnotes

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Authors' Contribution: Hamid Kassiri and Farzaneh Kamali designed and supervised the project. FK collected the specimens. HK, FK and SM H prepared, measured and identified the specimens. Arian Kasiri, RK, SM H, ML and Arvin Kasiri performed the statistical analyses and interpreted the data. HK, FK, Arian Kasiri, RK and Arvin Kasiri drafted the study. FK and HK revised the study for important content. HK, FK, RK, Arian Kasiri and Arvin Kasiri wrote and edited the manuscript. HK, FK, Arian Kasiri, RK, ML and Arvin Kasiri revised the manuscript.

Conflict of Interests Statement: Some authors are related; however, all authors independently contributed to study conception, design, data collection, analysis, and manuscript writing. Familial relationships did not influence the research process, data interpretation, or reporting of results. All authors meet the criteria for authorship as defined by the ICMJE."

Ethical Approval: This study was approved and registered by the Ethics Committee of Research at Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran. The study was conducted after obtaining permission from the Research Ethics Committee of the University (IR.AJUMS.REC.1402.624) on 2024/02/03.

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