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# Morphometric Identification of Gemlik Horse and Crossbreds

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**ABSTRACT** This study aimed to morphometrically characterize Gemlik horses and their crossbreds, which originated from Holsteiner and KWPN lineages and have been bred since the early 2000s under the Turkish Ministry of National Defense. A total of 111 horses including pure Gemlik, Gemlik crossbred, and parental lines-were evaluated for various body measurements such as withers height, croup height, body length, chest depth, heart girth, neck length, and ear dimensions. Data were analyzed using the Kruskal-Wallis nonparametric test followed by Bonferroni-corrected post hoc comparisons due to the non-normal distribution of the data. Results revealed significant differences ($p<0.05$) among breeds for body length, heart girth, and interocular distance. Gemlik horses exhibited measurements generally aligned with their paternal Holsteiner and maternal KWPN lines, particularly in withers height (~166 cm) and live weight (~514 kg). Gender-based comparisons showed mares were significantly larger than stallions in several traits, including live weight, hind leg length, and chest width. Age also significantly influenced skeletal and muscular development, with older horses demonstrating greater withers height, body length, and heart girth. The findings suggest that Gemlik horses possess morphometric traits suitable for sport horse purposes, especially show jumping. The formal recognition of the Gemlik breed as a Turkish sport horse could support the development of national equestrian activities, accelerate its international competitiveness, and increase the recognition of equestrian sports among a wider audience.

***Keywords:*** *Animal breeding, Body height, Body weight, Horse, Morphometry, Quantitative trait.*

**ÖZ**

## Gemlik Atı ve Melezlerinin Morfometrik Olarak Tanımlanması

Bu çalışma, 2000'li yılların başından beri Türk Millî Savunma Bakanlığı çatısı altında Holsteıner X KWPN ırklarının melezlenmesiyle geliştirilen Gemlik ve Gemlik melezi atların morfometrik özelliklerini tanımlamayı amaçlamıştır. Toplam 111 baş attan (saf Gemlik, melezler ve ebeveyn ırklar) alınan veriler; cidago yüksekliği, sağrı yüksekliği, vücut uzunluğu, göğüs derinliği, göğüs çevresi, boyun uzunluğu ve kulak ölçüleri gibi morfometrik özellikler açısından incelenmiştir. Verilerin normal dağılım göstermemesi nedeniyle Kruskal-Wallis nonparametrik testi ve Bonferroni düzeltmeli çoklu karşılaştırmalar kullanılmıştır. Irk özelliklerine göre vücut uzunluğu, göğüs çevresi ve gözler arası mesafe açısından istatistiksel olarak anlamlı farklılıklar ($p<0.05$) saptanmıştır. Gemlik atları, özellikle ~166 cm cidago yüksekliği ve ~514 kg canlı ağırlık ile Holsteıner ve KWPN ırklarına benzer özellikler taşımaktadır. Cinsiyet analizlerinde dişilerin, erkeklerden canlı ağırlık, arka bacak uzunluğu ve göğüs genişliği gibi birçok ölçümde daha yüksek değerlere sahip olduğu görülmüştür. Yaş arttıkça iskelet ve kas gelişimine bağlı olarak cidago yüksekliği, vücut uzunluğu ve göğüs çevresinde artışlar kaydedilmiştir. Bulgular, Gemlik atının engel atlama spor dalı için uygun morfometrik yapıya sahip olduğunu göstermektedir. Gemlik atının bir Türk spor atı olarak tescil edilmesi, ulusal binicilik faaliyetlerinin gelişimini desteklemek ve uluslararası rekabet gücünü artırılmasını hızlandırarak binicilik sporunun daha geniş kitlelerce tanınmasını sağlayabilecektir.

***Anahtar Kelimeler:*** *At, Hayvan ıslahı, Kantitatif özellik, Morfometri, Vücut ağırlığı, Vücut yüksekliği.*

## INTRODUCTION

Horses, which have helped people in food, transportation, agriculture, trade, and warfare throughout history, were domesticated by the Turks in the Botai (Northern Kazakhstan) region of Turkestan about 5.500 years ago (Henner et al. 2002; Ünver 2006; Gücüyener Hacan and Akçapınar 2011; Neves et al. 2017; Özbeyaz 2019; Bailey and Brooks 2020; Akçapınar and Özbeyaz 2021; Durmuş 2021; Grilz-Seger et al. 2021; Klecel and Martyniuk 2021; Librado and Orlando 2021; Olsen 2025). Archaeological

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excavations in the Botai region have uncovered evidence of human-controlled management practices, including harnessing, tethering, milking, and sheltering (Outram et al. 2009; Librado and Orlando 2021; Olsen 2025).

In the early days, people who relied on horses for food, such as milk and meat, later discovered additional benefits and began using them for transportation, agriculture, and trade (Taşkın 2012; Durmuş 2021; Kocakaya et al. 2023). Horses rapidly emerged on the battlefield, demonstrating their speed and strength (Ünver 2006; Taşkın 2012; Durmuş 2020; Durmuş 2021; Kocakaya et al. 2023).

Turkish civilization, originating in the wide steppes of Turkestan and referred to as "steppe culture," expanded through the domestication of the horse (Ünver 2006; Durmuş 2021). By 800 BC, Turkish culture transformed the function of the horse, advancing it from a basic provider of sustenance, agriculture, and trade to a riding animal, thereby conclusively undermining the supremacy of adjacent cultures dependent on horse-drawn chariots through their adept horse archers and spear cavalry (Ünver 2006; Durmuş 2020; Durmuş 2021). By 700 BC, the horse-drawn carriage had entirely diminished in military significance and was repurposed as a racing vehicle in the ancient Olympic Games (Ünver 2006; Mann and Scharff 2020).

According to reports, Hiao, the Turkish-born emperor of the Chou dynasty in 900 BC, participated in equestrian sports (Ünver 2006). In this case, the Turks became the first nation to use horses for sporting purposes, about 200–300 years before the Olympics, in addition to their skillful use as a means of warfare (Ünver 2006; Durmuş 2020; Durmuş 2021; Durmuş 2023).

The Turks held competitions in equestrian sports; cirit (javelin), çöğen (polo), and gökbörü were held as equestrian sports (Ünver 2006; Taşkın 2012; Durmuş 2021; Durmuş 2023; Acar 2024). Horse carriage races and horse races with and without riders, held in Greece, Rome, and Eastern Rome (Byzantium), which started with the Olympics, continued for many years. With the Renaissance, equestrianism and horse training were considered a science and even an art in Italy and France, and equestrian schools started to be opened in these countries (Ünver 2006). The use of horses in war and sports developed and changed until 1896, when the Olympics, which were banned in 394 AD due to church pressure, resumed. Cavalry units were formed in different styles, and horses suitable for these styles were raised.

In the modern era, horse competitions are organized in branches such as dressage, jumping, three-day eventing, horse endurance, horse racing, horse gymnastics, and pony (Ünver 2006; Taşkın 2012; OSC 2017; TBF 2025). Although many Turkish riders have achieved success in various contests, particularly "Atatürk's Cavalry" (ASEM 2025), interest in equestrian sports remains low owing to a lack of a Turkish sport horse breed and insufficient public awareness of the sport.

The present study aims to determine the morphometric characteristics of Gemlik horses and Gemlik hybrid horses, which are the progeny of the breeding and crossbreeding of the "Gemlik Horse" (Holsteiner X KWPN) breed, which commenced in the early 2000s at the Military Veterinary School and Training Center Command of the Land Forces Command, with the objective of developing a native sport horse breed for participation in national and international show jumping competitions and other sport events.

## MATERIAL AND METHODS

The Ankara University Animal Experiments Local Ethics Committee assessed the conformity of this research with ethical regulations, issuing a decision on 16.10.2024, numbered 2024-15-120.

The 111 horses included in the study comprised Gemlik, Gemlik crossbred, and parent line horses, all reared under the auspices of the Ministry of National Defense. The horses were weighed in kilograms (kg) using a scale that could detect half-kilogram increments. We measured the horses' Withers Height (WH), Croup Height (CrH), Front Leg Length (FLL), Hind Leg Length (HLL), Body Length (BL), Back Length (BaL), Chest Depth (CD), and Chest Width (CW) using a measuring cane. A tape measure was used to measure HG (Heart Girth), HL (Head Length), FL (Face Length), NL (Neck Length), DBE (Distance Between Eyes), DBEa (Distance Between Ears), EL (Ear Length), EW (Ear Width), SC (Shank Circumference), CrW (Croup Width), and CrL (Croup Length) in centimeters (Figure 1).

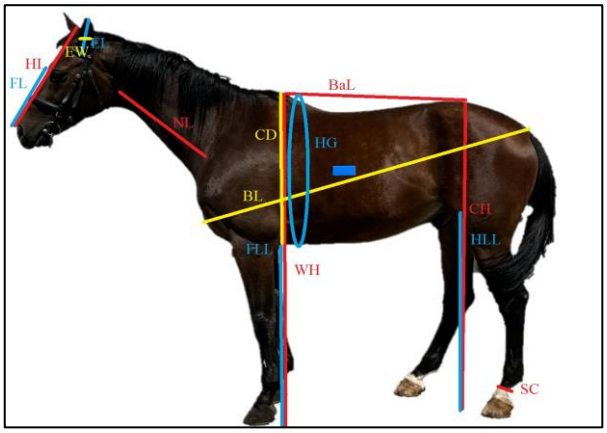


**Figure 1:** Some Body Dimensions on Gemlik horse.

### Statistical Analysis

Power analysis was not performed, as the study was descriptive in nature and based on the available population.

The Shapiro-Wilk normality test was applied to the data obtained from 111 heads of horses for the morphometric identification of the Gemlik, and it was determined that the majority of the data did not comply with the normal distribution. For this reason, the Kruskal-Wallis non-parametric test was used to analyze the differences in morphometric characters between breed and age and the Mann-Whitney U test for the gender groups for the data obtained from 111 horses, which were the subject of the study. As a result of Kruskal-Wallis test, Bonferroni corrections were made for the characters whose differences were significant, and the analyses were finalized. All analyses were conducted using SPSS 30.0.

## RESULTS

A normality test was applied to the data obtained as a result of the measurements. Since it was determined that the majority of the data did not comply with the normal distribution, the Kruskal-Wallis nonparametric test was applied, and differences in morphometric characters between breed (Table 1), gender (Table 2), and age (Table 3) groups were analyzed. Bonferroni correction was used to identify the groups with significant differences. In the comparisons performed according to breed and crossbreeding type (Table 1), statistically significant differences were identified in body length (BL), heart girth

(HG), and distance between eyes (DBE) ($p<0.05$). No significant breed-related differences were observed for the remaining morphometric traits. Although some crossbred combinations tended to exhibit relatively higher values in body size and thoracic measurements, these differences were limited to specific traits and did not indicate a consistent overall superiority pattern across all parameters. Gender-based comparisons (Table 2) revealed significant differences in live weight (LW), front leg length (FLL), body length (BL), back length (BaL), chest depth (CD), heart girth (HG), face length (FL), and shank circumference (SC) ($p<0.05$). In general, mares demonstrated higher values in traits associated with body mass and thoracic development. However, no statistically significant differences were found between stallions and mares for withers height, croup height, neck length, distance between eyes, distance between ears, or ear measurements. These findings suggest that sexual dimorphism in the studied population is more evident in body mass and musculoskeletal robustness than in linear height traits. Age-related analyses (Table 3) demonstrated significant differences in withers height (WH), croup height (CrH), front leg length (FLL), croup length (CrL), body length (BL), back length (BaL), chest width (CW), heart girth (HG), neck length (NL), distance between eyes (DBE), distance between ears (DBEa), and ear length (EL) ($p<0.05$). These measurements generally showed an increasing tendency with advancing age, reflecting skeletal growth and muscular development. In contrast, live weight, hind leg length, several cranial measurements, ear width, and shank circumference did not differ significantly among age groups. Overall, the morphometric variation observed in the study population was primarily associated with specific body length and thoracic traits across breeds, body mass-related characteristics across genders, and skeletal growth-related parameters across age groups.

**Table 1:** Body measurements of Gemlik horse and crossbreeds according to breed and crossbreeding type.

| BD | | LW (kg) | | WH (cm) | | CrH (cm) | | FLL (cm) | | CrL (cm) | | HLL (cm) | | CrW (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Breed** | **N** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** |
| **GG** | 49 | 478.66 | 11.23 | 162.99 | 0.86 | 161.86 | 0.73 | 109.19 | 1.22 | 44.19 | 0.68 | 148.38 | 0.75 | 53.74 | 0.69 |
| **GH** | 21 | 488.52 | 15.34 | 166.71 | 0.96 | 163.82 | 0.84 | 113.86 | 1.52 | 46.76 | 1.04 | 150.43 | 1.15 | 57.02 | 1.07 |
| **GK** | 14 | 457.96 | 6.22 | 164.50 | 0.75 | 160.86 | 0.98 | 114.14 | 0.84 | 43.68 | 0.56 | 146.68 | 2.62 | 56.21 | 1.49 |
| **HolG** | 10 | 516.25 | 27.05 | 165.10 | 1.05 | 163.40 | 1.49 | 112.00 | 2.24 | 47.20 | 1.66 | 151.40 | 1.74 | 57.60 | 1.01 |
| **HolK** | 7 | 514.29 | 39.20 | 166.00 | 0.91 | 162.71 | 1.06 | 113.43 | 2.59 | 45.86 | 1.62 | 149.86 | 1.40 | 56.14 | 2.30 |
| **KG** | 5 | 555.60 | 50.71 | 167.00 | 0.71 | 165.20 | 0.86 | 111.80 | 5.44 | 48.40 | 1.17 | 148.10 | 1.81 | 58.60 | 3.31 |
| **KWPN** | 5 | 477.50 | 40.98 | 166.90 | 2.52 | 163.40 | 2.38 | 113.60 | 1.36 | 46.20 | 2.06 | 151.20 | 2.24 | 53.20 | 1.24 |
| **p** | | 0.177 | | 0.095 | | 0.236 | | 0.311 | | 0.083 | | 0.321 | | 0.056 | |
| **BD** | | **BL (cm)** | | **BaL (cm)** | | **CW (cm)** | | **CD (cm)** | | **HG (cm)** | | **HL (cm)** | | **FL (cm)** | |
| **Breed** | **N** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** |
| **GG** | 49 | 157.92 | 0.97 | 65.76 | 1.76 | 41.60 | 0.82 | 71.58 | 0.75 | 186.00 | 1.61 | 52.86 | 0.44 | 36.30 | 0.47 |
| **GH** | 21 | 161.58 | 0.63 | 61.54 | 2.30 | 40.54 | 0.55 | 73.52 | 1.00 | 189.83 | 1.64 | 53.23 | 0.53 | 35.55 | 0.57 |
| **GK** | 14 | 159.54 | 1.07 | 56.86 | 1.01 | 37.64 | 0.83 | 72.29 | 0.62 | 185.48 | 0.99 | 52.68 | 0.38 | 36.21 | 0.58 |
| **HolG** | 10 | 160.65 | 1.34 | 63.40 | 2.92 | 41.70 | 2.14 | 75.20 | 1.23 | 191.30 | 2.78 | 52.55 | 0.96 | 37.60 | 0.70 |
| **HolK** | 7 | 166.64 | 2.51 | 64.57 | 3.77 | 42.36 | 2.15 | 74.00 | 2.16 | 189.93 | 4.00 | 54.71 | 1.04 | 37.43 | 1.34 |
| **KG** | 5 | 161.80 | 1.96 | 70.60 | 6.98 | 41.80 | 2.31 | 76.40 | 5.56 | 197.60 | 2.91 | 54.80 | 0.58 | 37.70 | 0.94 |
| **KWPN** | 5 | 159.50 | 3.91 | 64.60 | 5.44 | 41.40 | 1.11 | 72.60 | 2.73 | 191.00 | 4.59 | 50.90 | 0.68 | 35.80 | 1.02 |
| **p** | | 0.041 | | 0.169 | | 0.119 | | 0.339 | | 0.022 | | 0.071 | | 0.312 | |
| **BD** | | **NL (cm)** | | **DBE (cm)** | | **DBEa (cm)** | | **EL (cm)** | | **EW (cm)** | | **SC (cm)** | | | |
| **Breed** | **N** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | | |
| **GG** | 49 | 56.22 | 0.84 | 18.13 | 0.21 | 15.35 | 0.32 | 16.67 | 0.20 | 5.64 | 0.08 | 19.97 | 0.17 | | |
| **GH** | 21 | 54.31 | 0.88 | 17.10 | 0.30 | 14.88 | 0.28 | 16.29 | 0.39 | 5.71 | 0.12 | 20.31 | 0.20 | | |
| **GK** | 14 | 53.43 | 1.21 | 17.64 | 0.34 | 14.29 | 0.45 | 16.93 | 0.22 | 5.93 | 0.16 | 20.00 | 0.15 | | |
| **HolG** | 10 | 52.85 | 1.16 | 17.70 | 0.54 | 14.60 | 0.54 | 17.55 | 0.55 | 6.30 | 0.34 | 20.20 | 0.39 | | |
| **HolK** | 7 | 57.43 | 1.09 | 19.00 | 0.31 | 16.00 | 0.58 | 17.21 | 0.71 | 6.00 | 0.38 | 21.07 | 0.41 | | |
| **KG** | 5 | 52.40 | 1.17 | 19.10 | 0.40 | 14.30 | 0.37 | 16.90 | 0.40 | 6.20 | 0.37 | 21.70 | 0.77 | | |
| **KWPN** | 5 | 56.00 | 1.45 | 18.80 | 0.73 | 14.00 | 0.42 | 16.60 | 0.51 | 6.00 | 0.00 | 20.20 | 0.66 | | |
| **p** | | 0.05 | | 0.006 | | 0.108 | | 0.503 | | 0.110 | | 0.058 | | | |

Kruskal-Wallis was performed and $\alpha = 0.05$, Mean: Mean value, SE: Standard Error, GG: Gemlik, GH: Gemlik X Holsteiner, GK: Gemlik X KWPN, Holg: Holsteiner X Gemlik, Holk: Holsteiner X KWPN (Gemlik), KG: KWPN X Gemlik, KWPN: KWPN. BD: Body Dimensions, LW: Live Weight, WH: Withers Height, CrH: Croup Height, FLL: Front Leg Length, CrL: Croup Length, HLL: Hind Leg Length, CrW: Croup Width, BL: Body Length, BaL: Back Length, CW: Chest Width, CD: Chest Depth, HG: Heart Girth, HL: Head Length, FL: Face Length, NL: Neck Length, DBE: Distance Between Eyes, DBEa: Distance Between Ears, EL: Ear Length, EW: Ear Width, SC: Shank Circumference.

**Table 2:** Body measurements of Gemlik horses and crosses by gender.

| BD | | LW (kg) | | WH (cm) | | CrH (cm) | | FLL (cm) | | CrL (cm) | | HLL (cm) | | CrW (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SEX** | **N** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** |
| **Stallion** | 48 | 454.10 | 4.01 | 165.25 | 0.68 | 162.73 | 0.59 | 114.34 | 0.91 | 45.35 | 0.64 | 148.59 | 0.75 | 54.72 | 0.73 |
| **Mares** | 63 | 512.00 | 11.79 | 164.14 | 0.67 | 162.35 | 0.61 | 109.40 | 1.01 | 45.21 | 0.60 | 149.37 | 0.82 | 55.87 | 0.65 |
| **p** | | 0.001 | | 0.283 | | 0.463 | | <0.001 | | 0.969 | | 0.279 | | 0.124 | |
| **BD** | | **BL (cm)** | | **BaL (cm)** | | **CW (cm)** | | **CD (cm)** | | **HG (cm)** | | **HL (cm)** | | **FL (cm)** | |
| **SEX** | **N** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Breed** | **N** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** |
| **Stallion** | 48 | 158.53 | 0.82 | 60.21 | 1.37 | 40.31 | 0.64 | 70.91 | 0.62 | 185.02 | 0.89 | 53.31 | 0.39 | 37.27 | 0.34 |
| **Mares** | 63 | 160.88 | 0.77 | 66.38 | 1.48 | 41.45 | 0.68 | 74.21 | 0.71 | 190.51 | 1.41 | 52.75 | 0.34 | 35.69 | 0.39 |
| **p** | | 0.034 | | 0.001 | | 0.251 | | 0.002 | | 0.001 | | 0.282 | | 0.001 | |
| **BD** | | **NL (cm)** | | **DBE (cm)** | | **DBEa (cm)** | | **EL (cm)** | | **EW (cm)** | | **SC (cm)** | | | |
| **SEX** | **N** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | | |
| **Stallion** | 48 | 55.43 | 0.81 | 17.87 | 0.22 | 15.00 | 0.28 | 16.67 | 0.23 | 5.73 | 0.08 | 20.46 | 0.13 | | |
| **Mares** | 63 | 54.85 | 0.57 | 18.04 | 0.18 | 14.99 | 0.23 | 16.81 | 0.17 | 5.88 | 0.09 | 20.03 | 0.17 | | |
| **p** | | 0.876 | | 0.650 | | 0.850 | | 0.567 | | 0.359 | | 0.010 | | | |

Mann-Whitney U was performed and $\alpha = 0.05$, Mean: Mean value, SE: Standard Error. GG: Gemlik, GH: Gemlik X Holsteiner, GK: Gemlik X KWPN, Holg: Holsteiner X Gemlik, Holk: Holsteiner X KWPN (Gemlik), KG: KWPN X Gemlik, KWPN: KWPN. BD: Body Dimensions, LW: Live Weight, WH: Withers Height, CrH: Croup Height, FLL: Front Leg Length, CrL: Croup Length, HLL: Hind Leg Length, CrW: Croup Width, BL: Body Length, BaL: Back Length, CW: Chest Width, CD: Chest Depth, HG: Heart Girth, HL: Head Length, FL: Face Length, NL: Neck Length, DBE: Distance Between Eyes, DBEa: Distance Between Ears, EL: Ear Length, EW: Ear Width, SC: Shank Circumference.

**Table 3:** Body measurements of Gemlik horse and crosses according to their age.

| BD | | LW (kg) | | WH (cm) | | CrH (cm) | | FLL (cm) | | CrL (cm) | | HLL (cm) | | CrW (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Age** | **N** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** |
| **1** | **5** | 402.30 | 28.33 | 153.80 | 5.01 | 153.80 | 3.69 | 98.00 | 5.13 | 34.80 | 2.44 | 145.40 | 3.78 | 47.50 | 2.57 |
| **2** | **7** | 461.71 | 10.68 | 159.86 | 1.08 | 159.43 | 0.97 | 101.00 | 2.05 | 45.43 | 2.65 | 149.14 | 1.16 | 51.57 | 1.78 |
| **3** | **11** | 466.45 | 15.00 | 162.00 | 0.80 | 158.36 | 0.78 | 112.27 | 1.58 | 44.36 | 0.62 | 147.23 | 1.24 | 55.09 | 0.91 |
| **4** | **12** | 472.75 | 6.12 | 166.58 | 0.57 | 164.25 | 0.83 | 115.33 | 0.94 | 43.88 | 0.77 | 148.75 | 3.21 | 58.25 | 1.61 |
| **5** | **11** | 466.64 | 23.20 | 163.09 | 1.19 | 161.64 | 1.19 | 111.36 | 1.87 | 45.36 | 0.75 | 147.09 | 1.30 | 54.36 | 1.11 |
| **6** | **8** | 473.50 | 10.67 | 167.38 | 1.19 | 165.94 | 1.36 | 116.19 | 2.36 | 45.75 | 0.92 | 150.25 | 1.94 | 55.75 | 1.72 |
| **7** | **11** | 526.36 | 28.52 | 166.82 | 1.31 | 164.52 | 1.03 | 111.45 | 2.55 | 45.14 | 1.13 | 150.41 | 2.14 | 56.09 | 1.02 |
| **8** | **6** | 505.58 | 24.14 | 169.08 | 1.94 | 165.83 | 0.91 | 111.83 | 3.60 | 48.00 | 1.29 | 150.00 | 2.59 | 54.33 | 1.78 |
| **9** | **8** | 514.25 | 27.75 | 163.19 | 0.77 | 162.13 | 0.95 | 111.63 | 2.34 | 45.00 | 1.13 | 149.38 | 1.07 | 55.25 | 1.11 |
| **10** | **7** | 485.14 | 36.99 | 165.79 | 1.91 | 162.21 | 1.54 | 113.43 | 2.57 | 45.43 | 1.13 | 149.00 | 1.70 | 55.71 | 1.43 |
| **11** | **6** | 555.42 | 48.23 | 166.58 | 1.19 | 165.25 | 1.03 | 109.00 | 2.38 | 45.50 | 2.20 | 149.83 | 1.47 | 57.17 | 2.56 |
| **12** | **5** | 459.70 | 7.41 | 165.40 | 1.03 | 163.10 | 1.29 | 118.70 | 1.00 | 50.00 | 1.82 | 148.00 | 2.93 | 60.30 | 3.95 |
| **13** | **5** | 529.00 | 58.25 | 166.80 | 1.33 | 164.00 | 2.30 | 113.20 | 3.02 | 48.00 | 1.76 | 152.00 | 2.63 | 56.40 | 2.62 |
| **14** | **9** | 497.22 | 35.06 | 166.11 | 1.22 | 163.53 | 1.27 | 112.50 | 1.89 | 47.56 | 1.86 | 150.61 | 1.19 | 55.22 | 1.64 |
| **p** | | 0.218 | | <0.001 | | <0.001 | | 0.003 | | 0.013 | | 0.682 | | 0.115 | |

| BD | | BL (cm) | | BaL (cm) | | CW (cm) | | CD (cm) | | HG (cm) | | HL (cm) | | FL (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Age** | **N** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** |
| **1** | **5** | 144.40 | 2.94 | 67.70 | 1.93 | 38.10 | 1.38 | 62.40 | 3.59 | 170.60 | 6.52 | 50.30 | 0.30 | 39.40 | 0.60 |
| **2** | **7** | 156.29 | 1.44 | 82.00 | 2.93 | 44.57 | 3.35 | 72.86 | 1.28 | 180.43 | 2.07 | 52.14 | 0.83 | 37.14 | 2.14 |
| **3** | **11** | 156.86 | 1.29 | 55.55 | 1.32 | 36.77 | 1.07 | 72.18 | 0.60 | 185.43 | 1.41 | 52.32 | 0.69 | 36.18 | 0.71 |
| **4** | **12** | 161.33 | 0.91 | 60.58 | 1.54 | 39.79 | 1.09 | 73.25 | 0.73 | 188.92 | 1.29 | 52.71 | 0.50 | 36.42 | 0.72 |
| **5** | **11** | 159.00 | 1.11 | 59.41 | 3.58 | 40.27 | 1.12 | 72.73 | 2.07 | 185.86 | 2.25 | 52.86 | 1.09 | 35.91 | 0.77 |
| **6** | **8** | 161.31 | 0.80 | 58.38 | 1.52 | 39.25 | 0.80 | 72.31 | 0.75 | 186.88 | 3.14 | 54.00 | 1.10 | 36.75 | 1.18 |
| **7** | **11** | 159.89 | 1.55 | 69.18 | 3.56 | 41.02 | 1.60 | 75.00 | 1.89 | 191.86 | 2.62 | 53.23 | 0.86 | 36.50 | 1.12 |
| **8** | **6** | 163.67 | 0.84 | 68.83 | 3.78 | 44.67 | 3.80 | 72.17 | 2.36 | 186.17 | 4.20 | 55.83 | 1.51 | 35.67 | 0.88 |
| **9** | **8** | 159.81 | 1.48 | 63.88 | 3.91 | 41.38 | 1.15 | 74.13 | 1.13 | 191.63 | 3.26 | 52.13 | 1.08 | 34.88 | 0.77 |
| **10** | **7** | 160.21 | 2.11 | 58.71 | 4.18 | 41.43 | 0.79 | 72.57 | 1.46 | 193.14 | 3.79 | 53.21 | 0.85 | 35.79 | 0.92 |
| **11** | **6** | 162.75 | 1.28 | 69.17 | 6.21 | 43.58 | 1.67 | 76.25 | 2.14 | 197.17 | 4.19 | 53.00 | 0.82 | 35.00 | 0.68 |
| **12** | **5** | 160.70 | 2.19 | 60.40 | 4.52 | 40.30 | 1.20 | 70.60 | 2.38 | 188.10 | 0.64 | 53.00 | 0.61 | 36.80 | 0.87 |
| **13** | **5** | 167.60 | 3.03 | 64.80 | 3.23 | 43.80 | 3.32 | 75.60 | 2.64 | 192.40 | 6.30 | 55.80 | 1.36 | 38.40 | 1.69 |
| **14** | **9** | 163.19 | 2.30 | 62.69 | 4.59 | 42.47 | 1.28 | 73.06 | 2.15 | 191.39 | 3.11 | 52.47 | 0.70 | 36.17 | 0.72 |
| **p** | | <0.001 | | <0.001 | | 0.026 | | 0.114 | | 0.010 | | 0.065 | | 0.421 | |

| BD | | NL (cm) | | DBE (cm) | | DBEa (cm) | | EL (cm) | | EW (cm) | | SC (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ageed** | **N** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** | **Mean** | **SE** |
| **1** | **5** | 64.50 | 3.52 | 20.20 | 0.20 | 19.20 | 1.19 | 16.53 | 0.14 | 5.67 | 0.12 | 19.60 | 0.68 |
| **2** | **7** | 57.57 | 3.26 | 18.71 | 0.68 | 15.79 | 0.96 | 17.12 | 0.74 | 6.02 | 0.57 | 20.43 | 0.43 |
| **3** | **11** | 52.82 | 0.85 | 17.27 | 0.24 | 13.64 | 0.31 | 17.18 | 0.42 | 5.73 | 0.14 | 19.73 | 0.30 |
| **4** | **12** | 52.79 | 1.45 | 17.50 | 0.48 | 14.58 | 0.54 | 16.96 | 0.28 | 6.08 | 0.15 | 20.00 | 0.25 |
| **5** | **11** | 54.64 | 1.18 | 17.91 | 0.37 | 15.00 | 0.38 | 16.86 | 0.27 | 5.55 | 0.16 | 19.73 | 0.51 |
| **6** | **8** | 54.38 | 1.05 | 17.88 | 0.13 | 15.13 | 0.69 | 17.13 | 0.40 | 5.69 | 0.16 | 20.17 | 0.48 |
| **7** | **11** | 54.00 | 0.94 | 17.45 | 0.57 | 14.55 | 0.52 | 15.86 | 0.39 | 5.68 | 0.12 | 19.73 | 0.20 |
| **8** | **6** | 54.17 | 2.73 | 18.75 | 0.44 | 15.17 | 0.46 | 16.92 | 0.80 | 6.00 | 0.37 | 20.67 | 0.40 |
| **9** | **8** | 56.00 | 1.43 | 16.88 | 0.35 | 14.00 | 0.46 | 15.88 | 0.67 | 5.75 | 0.16 | 20.19 | 0.19 |
| **10** | **7** | 54.71 | 1.80 | 17.71 | 0.27 | 15.21 | 0.24 | 17.36 | 0.32 | 5.86 | 0.26 | 20.60 | 0.37 |
| **11** | **6** | 55.50 | 0.96 | 18.67 | 0.61 | 15.00 | 0.63 | 17.50 | 0.67 | 6.17 | 0.21 | 21.00 | 0.52 |
| **12** | **5** | 53.10 | 1.21 | 17.00 | 0.99 | 14.40 | 0.66 | 15.00 | 0.88 | 5.40 | 0.25 | 21.00 | 0.55 |
| **13** | **5** | 58.60 | 0.83 | 19.00 | 0.32 | 16.20 | 0.20 | 18.40 | 0.51 | 6.60 | 0.40 | 21.00 | 0.45 |
| **14** | **9** | 55.39 | 1.22 | 18.50 | 0.50 | 14.89 | 0.61 | 16.17 | 0.41 | 5.56 | 0.18 | 20.56 | 0.47 |
| **p** | | 0.047 | | 0.002 | | 0.018 | | 0.038 | | 0.160 | | 0.142 | |

Kruskal-Wallis was performed and α = 0.05 Mean: Mean value, SE: Standard Error. GG: Gemlik, GH: Gemlik X Holsteiner, GK: Gemlik X KWPN, Holg: Holsteiner X Gemlik, Holk: Holsteiner X KWPN (Gemlik), KG: KWPN X Gemlik, KWPN: KWPN. BD: Body Dimensions, LW: Live Weight, WH: Withers Height, CrH: Croup Height, FLL: Front Leg Length, CrL: Croup Length, HLL: Hind Leg Length, CrW: Croup Width, BL: Body Length, BaL: Back Length, CW: Chest Width, CD: Chest Depth, HG: Heart Girth, HL: Head Length, FL: Face Length, NL: Neck Length, DBE: Distance Between Eyes, DBEa: Distance Between Ears, EL: Ear Length, EW: Ear Width, SC: Shank Circumference.

## DISCUSSION AND CONCLUSION

The objective of the study was descriptive morphometric characterization rather than hypothesis testing of treatment or group effects, and since the sample size was constrained by population availability, power analysis was not conducted.

Size and morphometry are critical characteristics in practically all horse breeds. Numerous breed registries evaluate horses based on functional criteria and promote the breeding of horses with body types best suited for certain roles (Paksoy and Ünal 2019; Kaya et al. 2024).

When the body measurements of Gemlik and Crosses were evaluated according to their breed and crossbreeding type, KWPNXGemlik cross horses had higher values than Gemlik, KWPN, and other GEMLİK cross horses in terms of LW, WH, CH, CL, CW, BaL, CD, HG, HL, FL, HLL, and SC. The Gemlik (HolsteinerXKWPN) horse had greater values in terms of FLL, BL, CW, NL, and DBEa than the KWPN and other Gemlik crosses. HolsteinerxGemlik cross horses, on the other hand, had higher values in terms of HLL, DBEa, and EW than Gemlik, KWPN, and other Gemlik crosses.

The LW (514.29) of Gemlik horses, resulting from the crossbreeding of Holsteiner (Kelley 2002; Pitts and Shang 2016) and KWPN (Pitts and Shang 2016), both of which are half-blood and medium-weight breeds, varied from 449.00 to 800.50 kg, as recorded for Holsteiner; however, it was low to the 549.00-599.00 kg range reported for KWPN. The LWs of Gemlik horses were higher than the mean LW (Table 1) determined for KWPN in the same study. It was found to be higher than the weights reported by Taşkın (2012) for KWPN at the ages of 12 months (345.08 kg) and 24 months (468.86 kg), but similar to the average weight of 516.66 kg at the age of 36 months.

The average wither height (WH) of 166.00 cm in Gemlik horses is comparable to the Holsteiner breed (163–173 cm), which represents the paternal lineage. This measurement exceelineage andously reported values of 145.13–161.3 cm and 163.00 cm for the KWPN breed,

which is the maternal lineage, and aligns closely with the average value of 166.90 cm established in this study. In addition, the height of the stallion was found to be similar to the values reported by the Turkish Patent and Trademark Office for the Gemlik horse in 2002 (145.0-170.00 cm) (Türk Patent 2025).

The average croup height of Gemlik horses, measured at 162.71 cm, was found to be lower than the 163.40 cm recorded for KWPN in the same research and comparable to previously published figures for the KWPN breed (Taşkın 2012).

The heart girth (HG) of Gemlik horses was determined to be 189.93 cm in this research. This value was close to the 191.00 cm measurement established for KWPN in this research; however, it was smaller, similar to the 158.59–190.48 cm range documented for the KWPN breed (Taşkın 2012) and comparable to the 150.00–200.00 cm range (Türk Patent 2025) previously noted for the Gemlik horse.

The study revealed that the mean chest width (CW) of Gemlik horses was 42.36 cm, comparable to the 41.40 cm recorded for the maternal line KWPN within the same research. However, this measurement was significantly lower than the previously documented value of 47.63 cm for the father line Holsteiner breed (Alagić et al. 2002). The chest depth of 74.00 cm observed in Gemlik horses exceeds the 72.60 cm recorded for KWPN, which serves as the primary reference in the same study. The values observed were comparable to the 73.50–74.35 cm range reported for the Holsteiner breed, which represents the paternal lineage (Alagić et al. 2002). The study found that the shank circumference value of 21.07 cm for Gemlik horses aligns with previously reported values of 19–21 cm. Additionally, the value of 20.20 cm for the KWPN, a primary line, is consistent with earlier reports of 19.23–21.03 cm for the KWPN breed (Brown and Carton 2021). In the same study, the body length of 166.64 cm for Gemlik horses was found to exceed the 159.50 cm recorded for the maternal line KWPN (Brown and Carton 2021), while being lower than the 172.32-173.14 cm values reported for the HOLSTEINER breed, which was previously the paternal line (Alagić et al. 2002).

The Kruskal-Wallis test was conducted on the data from Gemlik and Gemlik cross horses, with Bonferroni correction used for multiple comparisons. It was concluded that the statistical differences between Gemlik and Crosses were substantial ($p<0.05$) for BL, HG, and DBE traits. The body length (BL) differed significantly between Gemlik and Gemlik Cross horses. The post hoc test revealed significant differences among KWPN-Gemlik horses, GG-GK crosses, GG-Gemlik horses, and KG-GH crosses ($p<0.05$). Upon using the Bonferroni correction, the comparisons yielded insignificant results ($p>0.05$).

Upon evaluating the body measurements of Gemlik and Crosses by gender, it was noted that mares had superior LW values in comparison to stallions. End-gestational live weight in mares is 13-14% more than the beginning-gestational LW (Paksoy and Güngör, 2023). This differential is attributed to the mares' greater use for breeding rather than competing. Upon evaluating Table 2, it is evident that mares exhibit superior values in HLL, CW, BL, BaL, CD, SC, HL, DBE, DBEa, and EW characteristics compared to stallions. The Mann-Whitney U test findings indicated significant variations in body structure-related characteristics, including LW, FLL, BL, BaL, CD, HG, FL, and SC, based on gender ($p<0.05$).

When the body measurements of Gemlik and Crosses were evaluated according to their genders, the differences between the age groups in the characters of WH, CH, FLL, CW, BL, BaL, CW, HG, NL, DBE, DBEa, and EL were significant ($p<0.05$). Measurements such as BL, WH, CH, and FLL are usually related to skeletal growth, so they are expected to increase with age. The results obtained in the study confirm this expectation (Table 3). Heart Girth (HG) is related to respiratory capacity and muscle development. There is a significant increase in groups that have reached adulthood at the age of six and above (Table 3). In general, significant differences in certain characteristics are observed among age groups, which is believed to be due to the use of the Holsteiner breed as the paternal line.

The body measures of the Gemlik horse analyzed in the study were compared with those of the Holsteiner paternal line and the KWPN maternal line. The breeds, including both the paternal and maternal lineages of the Gemlik horse, are used as jumping sport horses. The body dimensions of the Gemlik horse closely reflect those of the Holsteiner lineage, which is its paternal line. Further research is required on the Gemlik horse, now competing in events organized by the Turkish Equestrian Federation as a show jumper, particularly about its paternal and maternal lineage, and it should be officially classified as a Turkish sports horse. This aspect is expected to elevate and promote Turkish equestrian sport, augmenting its worldwide prominence. This acknowledgment may result in greater investment in breeding programs and training facilities, hence enhancing competitive stature internationally. As interest in the Gemlik horse increases, chances for cooperation and interaction among equestrian enthusiasts globally may also expand.

## CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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## AUTHOR CONTRIBUTIONS

Idea/Concept: AK, NÜ, CÖ
Supervision/Consultancy: NÜ, CÖ
Data Collecting and/or Processing: AK, RD
Analysis and/or Interpretation: AK
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Critical Review: NÜ, CÖ

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