

# Morphometric Characterization of Minahasa Horse for Breeding and Conservation Purposes

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**Morphometric Characterization of Minahasa Horse for  
Breeding and Conservation Purposes**

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**ABSTRAK**

Penelitian ini bertujuan untuk melihat adanya keragaman morfometrik pada populasi kuda Minahasa. Bobot badan dan ukuran-ukuran tubuh diukur pada 505 ekor kuda Minahasa (195 betina & 310 jantan). Deskripsi bentuk dan ukuran tubuh dilakukan terhadap empat subpopulasi kuda lokal yang berada di Kota Tomohon, Kota Manado, Kabupaten Minahasa Selatan, dan Kabupaten Minahasa dengan menggunakan pendekatan analisis multivarian. Metode statistika yang digunakan adalah model linier umum, analisis diskriminan sederhana, dan analisis komponen utama untuk membuat konstruksi pohon kekerabatan. Hasil penelitian menunjukkan bahwa populasi kuda Tomohon mempunyai bobot badan dan ukuran tubuh lebih tinggi daripada subpopulasi kuda di ketiga daerah lainnya (Kota Manado, Kabupaten Minahasa Selatan, dan Kabupaten Minahasa). Faktor pembeda utama kuda lokal Minahasa adalah lebar pinggul. Hasil penelitian ini sangat bermanfaat dalam upaya mendukung strategi dasar dalam usaha pemanfaatan dan pengembangan kuda dari sumberdaya yang telah beradaptasi dengan lingkungan lokal setempat.

*Kata kunci: morfometrik, kuda minahasa, kekerabatan*

**ABSTRACT**

The objective of this study was to investigate morphometric variation of Minahasa horses. Body measurements and live-weight were taken on 195 mare and 310 stallion of Minahasa horse. A multivariate approach was adopted to provide description of both body shape and body size of four Minahasa local horse populations, i.e. Tomohon, Manado, South Minahasa, and Minahasa. Statistical methods employed in this study were general linear model, simple discriminant analysis, and principle component analysis were used to construct phylogenetic trees. The results showed that Tomohon's horse population had higher body weights and body measurements ( $P < 0.05$ ) than those from three other areas (Manado, South Minahasa, and Minahasa). The hip width is the most discriminant variable to determine the differences among Minahasa local horse population. The results support establishment of strategy to promote the use and the development of local adapted horse.

*Key words: morphometric, Minahasa horses, phylogenetic*

**INTRODUCTION**

Breed characterization of indigenous animal is the initial approach to a sustainable use of its animal genetic resource (Lanari *et al.*, 2003). Despite the modernization of agriculture, Minahasa local horse, in North Sulawesi plays an important role in the rural area. The horses are

mainly used in agriculture, light traction, riding and leisure activities. Recent global strategies include several techniques such as: classifying and accepting a unique genetic resource in a specific area and improving the proper use of the related variety (FAO-AAAS, 1994). In order to differentiate variation in both size and shape, body measurements of animals were used to describe morphological differentiation in large animals (Gilbert *et al.*, 1993; Shahin *et al.*, 1995). Analysis of morphological traits has currently continued as an ongoing research in the fields of horse breeding and genetics, as well as the

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investigation of their origin (Komosa & Purzyc, 2009). Yakubu *et al.* (2005) found that body measurements have regularly been used as the weights estimation while weight was measured along with these parameters. Analysis of variance and correlations are extensively used to characterize the phenotypic and genetic relationships among body measurement (Dietl *et al.*, 2005). Yet, principal component analysis is a valuable method when physical characteristics are related. Recently, other body measurements and indices estimated from various combinations of conventional and non-conventional body constraints are also used as indicators of type and function in local animals, not merely provide superior guide to weight prediction (Salako, 2006). As the perspective of both animal genetics and animal improvement, principal components analyses are considered in clustering traits which possibly used for selection and in studying the interdependence of body size measurements of large animals, including local horses.

Nowadays, interrelationship among body size measurement of horse has not been widely exploited. Consequently, the present study was embarked upon to examine the variation of body measurements of Minahasa local horse and to study the relationship among their body measurement in order to obtain a simple method to describe their variation for genetic and breeding purposes using principal component factor analysis.

## MATERIALS AND METHODS

### Location of Study

The study was carried out in North Sulawesi province started from June to August 2009. The chosen areas are inhabited by Minahasa horses in large number and distributed at 4 districts, namely Minahasa (H), South Minahasa (S), Tomohon (T) city, and Manado (M) city. Minahasa and Tomohon city are categorized as agriculture region with altitude is 600-700 m above sea level. Meanwhile, South Minahasa, and Manado city are categorized as coastal area.

### Experimental Animals

The number of Minahasa local horses that randomly selected in the study was 505 horses (310 males and 195 female). Age was ranged between two and seven years. The unhealthy and pregnant ones were excluded. Age was primarily determined by dentition as described by Owen & Bullock (2002).

### Measured Traits

After the individual age group was confirmed, eleven different body measurements were taken on each horse population. These include: wither height (WH), the distance from the highest point of the *processus spinalis* of the *vertebra thoracica* to the ground; body length (BL), measured from distance between the site of pins (*Tuber ischii*) to tail drop (*berositas humeri*); chest width (CW), measured as the distance from left to the right

upper arm (*pars cranialis of the tuberculum majus humeri*); chest depth (CD), measured as the distance between the highest point of the *processus spinalis* of the *vertebra thoracica* to lowest point of chest; heart girth (HG), measured as body circumference just behind the forelegs; rump height (RH), height of hip; rump length (RL), measured from hips (*Tuber coxae*) to pins (*Tuber ischii*); hip width (HW), width of rump/hip (*Tuber coxae*); face length (FL), distance from between prelock to the lower lip; collar length (CL), measured from distance between the ear site to the site of pins (*Tuber ischii*) and face width (FW), measured as the widest point of the head. Height measurements were assessed by using a graduated measuring stick, the length and circumference used a flexible tape, meanwhile calibrated wooden caliper was used for the width measurements. The procedure and anatomical reference points for the respective body measurements with fewer modifications described elsewhere by Salako & Ngere (2002). Pregnant horses data were excluded as sample due to anatomical changes (thoracic size) which can mislead the measurement. Measurements were done by the same person to avoid from human error.

### Statistical Analysis

General linear model was used to analyze groups of region and sex's association. Pearson's coefficients of correlation ( $r$ ) among the various morphometric traits were estimated. From the correlation matrix, data were generated for the principal component factor analysis. Principal component analysis according to Everitt *et al.* (2001) is a method for transforming the variables in a multivariate data set ( $X_1, X_2, \dots, X_p$ ) into new variables ( $Y_1, Y_2, \dots, Y_p$ ) which are uncorrelated with each other and account for decreasing proportions of the total variance of the original variables defined as:

$$y_1 = a_{11}x_1 + a_{12}x_2 + \dots + a_{1p}x_p$$

$$y_2 = a_{21}x_1 + a_{22}x_2 + \dots + a_{2p}x_p$$

$$y_p = a_{p1}x_1 + a_{p2}x_2 + \dots + a_{pp}x_p$$

The following indices were calculated from the mean values of body measurements for each area group including the gender group, based on the methods of Person (1999):

$$\text{Weight index (WI)} = \frac{\text{body length} \times \text{chest girth} \times (\text{hip width} + \text{chest width})}{2}$$

$$\text{Length index (LI)} = \frac{\text{body length}}{\text{wither height}}$$

$$\text{Height slope (HS)} = \frac{\text{wither height}}{\text{rump height}}$$

$$\text{Width slope (WS)} = \frac{\text{hip width}}{\text{chest width}}$$

$$\text{Depth index (DI)} = \frac{\text{chest depth}}{\text{wither height}}$$

$$\text{Foreleg length (FL)} = \text{wither height} - \text{chest depth}$$

$$\text{Balance (B)} = \frac{(\text{rump length} \times \text{hip width})}{(\text{chest depth} \times \text{chest width})}$$

$$\text{Cumulative index (CI)} = \frac{(\text{weight}/\text{breed average weight}) + \text{length index} + \text{balance}}$$

Correlation among the indices was also computed for each district and sex group. The data were analyzed by using general linear model, principle component analysis, discriminant, canonical, and clustering (Nei *et al.*, 2007).

## RESULTS AND DISCUSSION

## Morphometric Parameters

The male horses (122.59±9.77 cm) were slightly taller than female horses (121.45±8.41 cm) (Table 1). The size is almost similar to the body size of pony horses at the same age. The horse population in Tomohon city had the highest size of WH (134.42±10.12 cm), suggested that the horse's wither height is distinctly differed from those from other localities. Most of the Tomohon sub-population horses were mixed between racehorse breed like *thoroughbred* and local horse. However, some local horse populations in Minahasa were speculated that they were originated from the crossing of many breeds for centuries. Noor (2008) affirmed that the adaptation to environment which yielded a fertilized offspring were good to develop as indigenous breeds since the ability to adapt to the specific environmental pressure.

The same phenomena were found for BL, RL, FL measurements and all indices values except for WS and balance scores. Body measurements value showed a considerable high variation in all regions. The RH has a close relationship with the WH measurement. This

suggests that the animal was not sloppy on standing. Meanwhile, the HW and CW values showed that the animal was wider at the rump than at the shoulder. The average WH value across sexes was 121.45±8.4 cm and RH was 123.60±8.5 cm. The female horse was taller at the rump than at the withers. Horses were also wider at the rump (40.78±3.6 cm) than at the chest (28.10±4.3 cm). The descriptions of the populations based on the areas were presented in Table 1. In general, the Tomohon horse had significantly higher value of live weight and all body measurements than those of in the other regions. This indicates that the local horses in Tomohon city were bigger than three others area. There was a large difference between the live weights of horses from high and low altitude areas. The population that lived in higher altitude has bigger body size than the population in lower altitude. Considering quite a few measurements (HG, WH, RH, and FW), the horse from Manado and South Minahasa has similar body size measurement. Large body measurement variation indicates the absence of selection, and could be due to the influence of different environment. Specifically, the head length measurement exhibits very little variation because of its close association with cranial bone. The high variability shown by

Table 1. Morphological indices of the quantitative traits of Minahasa local horse

Variable (cm)	Sex		District			
	♂ (N= 310)	♀ (N= 195)	Manado (N= 57)	Minahasa (N= 374)	South Minahasa (N= 33)	Tomohon (N= 41)
LW (kg)	238.61±51.92	239.30±46.43	201.26±40.44 <sup>a</sup>	243.17±45.59 <sup>b</sup>	191.09±20.40 <sup>a</sup>	291.70±48.95 <sup>c</sup>
HG	144.30±11.14	145.80±12.18	136.72± 8.74 <sup>a</sup>	145.56±11.19 <sup>b</sup>	136.58± 4.87 <sup>a</sup>	156.42± 9.78 <sup>c</sup>
CW	28.08± 3.3	28.10± 4.34	25.63± 2.48 <sup>a</sup>	28.28± 3.83 <sup>b</sup>	26.64± 1.69 <sup>a</sup>	30.98± 3.02 <sup>c</sup>
CD	54.22± 5.58	54.44± 5.17	50.63± 3.95 <sup>a</sup>	54.32± 5.09 <sup>b</sup>	52.03± 2.97 <sup>a</sup>	61.25± 5.35 <sup>c</sup>
WH	122.59± 9.77	121.45± 8.4	116.54± 6.12 <sup>a</sup>	122.24± 8.59 <sup>b</sup>	116.06± 4.56 <sup>a</sup>	134.42±10.12 <sup>c</sup>
RH	123.05± 9.77	123.60± 8.46	117.49± 6.47 <sup>a</sup>	123.51± 8.77 <sup>b</sup>	117.64± 4.63 <sup>a</sup>	133.85±10.39 <sup>c</sup>
HW	39.04± 4.67	40.78± 3.58 <sup>**</sup>	33.91± 5.17 <sup>a</sup>	40.29± 3.56 <sup>b</sup>	38.55± 2.03 <sup>c</sup>	43.43± 3.89 <sup>d</sup>
BL	116.96± 6.54	118.67± 5.68 <sup>**</sup>	112.11± 5.93 <sup>a</sup>	118.22± 5.94 <sup>b</sup>	114.89± 3.81 <sup>ac</sup>	122.01± 5.79 <sup>d</sup>
RL	39.24± 3.84	40.31± 3.12 <sup>**</sup>	36.60± 2.87 <sup>a</sup>	39.88± 3.46 <sup>b</sup>	38.21± 1.87 <sup>ac</sup>	43.03± 3.44 <sup>d</sup>
CL	54.50± 5.48	54.07± 5.27	53.68± 4.25 <sup>a</sup>	54.38± 5.39 <sup>a</sup>	50.61± 4.50 <sup>b</sup>	57.93± 5.52 <sup>c</sup>
FW	20.01± 1.02	20.06± 1.09	19.54± 1.12 <sup>a</sup>	20.07± 1.01 <sup>b</sup>	19.42± 0.75 <sup>a</sup>	20.83± 0.87 <sup>c</sup>
FL	47.74± 3.43	48.61± 3.6 <sup>*</sup>	47.26± 3.07 <sup>a</sup>	48.41± 3.67 <sup>ab</sup>	45.00± 1.84 <sup>c</sup>	48.55± 2.17 <sup>abd</sup>
WI	57E4±12E3	40E4±74E3 <sup>*</sup>	46E4±9.7E4 <sup>a</sup>	59E4±10E3 <sup>b</sup>	33E4±3.8E3 <sup>ac</sup>	72E4±13E3 <sup>d</sup>
HS	1.00± 0.02	0.98± 0.02 <sup>**</sup>	0.99± 0.22 <sup>a</sup>	0.99± 0.02 <sup>a</sup>	0.99± 0.02 <sup>ab</sup>	1.01± 0.02 <sup>c</sup>
WS	1.40± 0.15	1.46± 0.13	1.33± 0.19 <sup>a</sup>	1.44± 0.14 <sup>b</sup>	1.45± 0.08 <sup>bc</sup>	1.41± 0.12 <sup>bcd</sup>
LI	0.96± 0.05	0.65± 0.03 <sup>**</sup>	0.96± 0.04 <sup>a</sup>	0.97± 0.05 <sup>a</sup>	0.65± 0.03 <sup>b</sup>	0.91± 0.04 <sup>c</sup>
DI	0.44± 0.02	0.45± 0.02 <sup>**</sup>	0.43± 0.02 <sup>a</sup>	0.44± 0.02 <sup>b</sup>	0.45± 0.02 <sup>bc</sup>	0.46± 0.02 <sup>cd</sup>
F	68.40± 4.98	67.01± 4.63 <sup>**</sup>	65.91± 3.35 <sup>a</sup>	67.92± 4.64 <sup>b</sup>	64.03± 3.05 <sup>ac</sup>	73.18± 5.53 <sup>d</sup>
Balance	1.02± 0.14	1.09± 0.12	0.96± 0.15 <sup>a</sup>	1.06± 0.13 <sup>b</sup>	1.07± 0.10 <sup>bc</sup>	0.99± 0.09 <sup>ac</sup>
CI	2.97± 0.25	2.74± 0.23 <sup>*</sup>	2.77± 0.24 <sup>a</sup>	3.05± 0.24 <sup>b</sup>	2.52± 0.15 <sup>ac</sup>	3.12± 0.19 <sup>d</sup>

Note: Means in the same rows with different superscript differ significantly ( $P < 0.05$ ); (\*)= significantly different ( $P < 0.05$ ); (\*\*) = significantly different ( $P < 0.01$ ). E= exponential; cv= coefficient of variation (%); LW= live weight; HG= heart girth; CW= chest width; CD= chest depth; WH= wither height; RH= rump height; HW= hip width; BL= body length; RL= rump length; CL= collar length; FW= face width; FL= face length; WI= weight index; HS= height slope; WS= width slope; LI= length index; DI= depth index; FI= foreleg index; CI= cumulative index; ♀= female horse/ mare and ♂= male horse/ stallion.



the large standard deviation values associated with the measurements can also be a reflection of wide disparity among the sample size which can not identified yet.

The low to medium coefficients of variation observed in all quantitative traits in both sexes and regions are attributable to the environmental sensitivity such as nutrition related conditions and temperature. Large variations within certain measurements suggest absence of selection. Sex influenced ( $P < 0.05$ ) the HW, BL, RL and FL measurements. Similarities between the body measurements of males and females have been reported in cattle (Salako & Ngere, 2002).

### Morphometric Indices

The mare had values of WS, DI, and Balance while for WI, LI, HS, FL, and CI stallion had higher values (Table 1). Based on the HS index the stallion is higher in the posterior area than mare. WS value describe that mare is narrower than stallion. In this case the CI appears more realistic because it takes more parameters into consideration more than other. Comparing the 4 regions, it can be concluded that the population in Tomohon city has the highest values of WI, HS, DI, FL, and CI. The South Minahasa population showed narrower at the fore quarter than the hind, longer and more balance bodies than three other populations based

on the WS, LI, and Balance indices. HS index indicate the horses in Tomohon are relatively sloppier than the horses in Manado, Minahasa, and South Minahasa.

Based on the calculated index the horses from Tomohon were generally has long legged and longer bodied. Phenotypically the horse is more look like race-horses. Furthermore, the horse from Manado and South Minahasa had the body proportion of working animals. The WS and LI are useful parameters for estimating balance, and could be important in the assessment of functionality. Based on this study, the WS differential indicated that the most of Minahasa local horses are typical mild draught horse. The body form (type, structure, and proportion) supposed to be ideal parameter for the productive animals (Salako, 2006).

### Canonical Analysis

The results of canonical analysis in Table 2 showed that the most discriminant variable was HW= 0.93. Other body measurements were not use as discriminate factor to all Minahasa horse populations. Mansjoer *et al.* (2007) reported that a lower number obtained from canonical analysis cannot be used as discriminate variables for horse populations.

Cluster analysis in Figure 1 showed that in general the body measurements in three populations (Manado,

Table 2. The total canonical structures

Var	LW	WH	BL	HG	CW	CD	RH	HW	HL	CL	FW	FL
Can 1	0.68	0.64	0.65	0.63	0.54	0.67	0.61	0.93	0.68	0.24	0.44	0.19
Can 2	-0.55	-0.62	-0.17	-0.46	-0.27	-0.50	-0.52	-0.04	-0.28	-0.49	-0.39	-0.27

Note: LW= live weight; HG= heart girth; CW= chest width; WH= withers height; RH= rump height; CD= chest depth; HW= hip width; BL= body length; HL= hip length; CL= collar length; FW= face width; FL= face length; Var=variable; Can 1= morphometric related to body measurement; Can 2= morphometric related to body dimension.

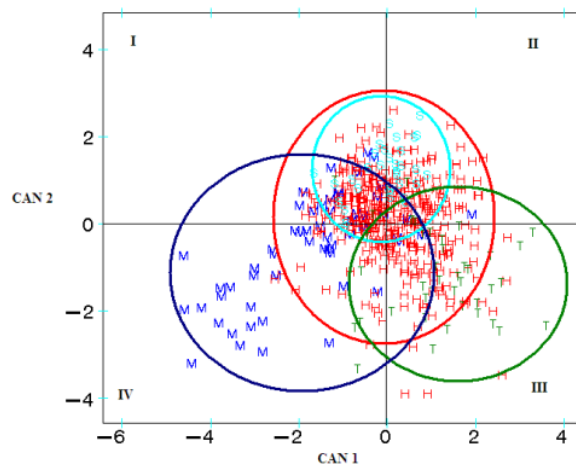


Figure 1. Phenotype distribution of Minahasa local horse population. M= Manado; S= South Minahasa; H= Minahasa; T= Tomohon; Can 1= morphometric related to body measurement; Can 2= morphometric related to body dimension; quadrant I-IV= the position of each population that are close to each other based on morphometric parameters.

Tomohon, and South Minahasa) were mixed with Minahasa horses. The Minahasa horses were placed at the center of quadrants, while the Manado horse was situated outside for quadrant four and Tomohon sub-population at quadrant three. Clearly, the Minahasa horses are probably the common local horse population. It is also possible that the Manado and Tomohon sub-populations were mixed with other groups.

**Principal Component Matrix**

The variables which have the closest association with main factor were BL, RH, RL, WH CD, and HG represent 53.5%–69.1% of the variance in the body measurements. These variables tended to describe the main body size measurement (Table 3). Fumio *et al.* (1982) and Hammock & Shrode (1986) reported that

the first principal component was a measure of overall size in Japanese black cattle performance in beef cattle. Karacaoren & Kadarmideen (2008) and Sadek *et al.* (2006) also reported that the first factor show the highest variation (54.8%–70.0%). The second factor describes 8.2% to 13.1% of the total variance of FL, FW, and CL. Conformation characters are good traits for selection and genetic evaluation. Body dimensions have been used to identify breed, origin, and relationship through the medium of head measurements or to indentified size and body shapes measured could improve selection for growth by enabling the breeder to recognize early maturing and late maturing animals based on the different body size measurements (Salako & Nbera, 2002). The two factors could be used to select animals based on a group of variables rather than on separated traits.

Table 3. Eigen values and share of total variance along with 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> factors loading after rotation of the body measurements of Minahasa local horse

N	Sex						Areas											
	♂ (N= 310)			♀ (N= 195)			Manado (N= 57)			Minahasa (N= 374)			South Minahasa (N= 33)			Tomohon (N= 41)		
	c	v	E	c	v	E	c	v	E	c	v	E	c	v	E	c	v	E
I	WH, RH, BL, HG, CD	66.1	7.3	WH, RH, HL, HW	61.0	6.7	WH, RH, BL, HG, CD, HW	55.5	6.1	WH, RH, BL, HG, HW	60.1	6.7	RH, BL, HG, HW	53.5	5.9	WH, RH, HG, CD, HW	69.1	7.6
II	CL, FL	8.2	0.9	CD	11.3	1.2	CL, FL	13.1	1.4	CW	9.5	1.0	CD, WH	11.5	1.3	CL, FL	8.4	0.9
III	FW	5.9	0.7	FL, FW	7.1	0.8	FW	7.6	0.8	FL, FW	6.7	0.7	CL, FL	8.3	0.9	FW, CW	7.1	0.8

Note: Extraction method: Principal Component Analysis; N=factor; c= component; v= variance (%); E= eigen value; LW= live weight; HG= heart girth; CW= chest width; WH= withers height; RH= rump height; CD= Chest Depth; HW= hip width; BL= body length; HL= hip length; CL= collar length; FW= face width; FL= face length; ♀= female horse/ mare and ♂= male horse/ stallion.

Table 4. Coefficients of correlation of the morphometric characters of Minahasa horse population

Traits	LW	HG	CW	CD	WH	RH	HW	BL	HL	CL	FW	FL
LW		0.79	0.63	0.82	0.87	0.85	0.78	0.76	0.83	0.61	0.64	0.48
HG	0.90		0.55	0.74	0.77	0.76	0.70	0.63	0.71	0.55	0.51	0.45
CW	0.67	0.60		0.56	0.61	0.59	0.57	0.53	0.60	0.40	0.51	0.29
CD	0.78	0.79	0.61		0.94	0.88	0.73	0.64	0.75	0.54	0.52	0.42
WH	0.86	0.82	0.67	0.88		0.95	0.75	0.71	0.83	0.62	0.59	0.46
RH	0.85	0.83	0.63	0.90	0.95		0.73	0.71	0.83	0.62	0.60	0.47
HW	0.80	0.76	0.61	0.70	0.74	0.74		0.66	0.76	0.44	0.49	0.35
BL	0.70	0.63	0.52	0.55	0.66	0.66	0.68		0.70	0.53	0.49	0.39
HL	0.835	0.78	0.65	0.69	0.81	0.80	0.77	0.65		0.57	0.59	0.49
CL	0.65	0.66	0.42	0.53	0.63	0.61	0.59	0.60	0.58		0.42	0.54
FW	0.44	0.44	0.39	0.37	0.43	0.40	0.43	0.32	0.48	0.31		0.35
FL	0.64	0.64	0.36	0.47	0.51	0.53	0.54	0.46	0.54	0.53	0.36	

Note: Significant at P<0.01 for all correlation coefficients. Upper matrix= male horses or stallions; Lower matrix= female horses or mares; LW= live weight; HG= heart girth; CW= chest width; CD= chest depth; WH= withers height; RH= rump height; HW= hip width; BL= body length; HL= hip length; CL= collar length; FW= face width and FL= face length.

### Phenotypic Correlations

Person's coefficients of correlation among the various traits are presented in Table 4. Positive and highly significant ( $P < 0.05/0.01$ ) correlation among the measurements suggests high predictability among the measurements although this was not tested. The coefficient ranged from 0.31 (FW/CL) to 0.95 (WH/RH) for the female body size and from 0.29 (HL/HG) to 0.95 (WH/RH) for male. Correlation analysis of the morphostructure indices exposed strong association between all body measurements and weight index for both male (0.46-0.92) and female (0.25-0.90). Most of the variable pairs were significantly ( $P < 0.05$ ) and positively correlated. Withers height was closely correlated with rump height. Positive correlation was found among parameters measured and body weight. Conversely, the head dimension shown a moderate associated.

### CONCLUSION

The cumulative index (CI) is suitable as an indicator of function, while the hip width (HW) is the appropriate variable to determine the differences of all Minahasa local horse populations. More importantly, there is a positive correlation between several body measurements and body weight.

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