The principal component of body height linear type traits and its relationship level to milk yields as Holstein cattle selection criterion

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Abstract

The essential body height characteristics associated with milk yields must be carefully identified. In particular, this study sought to identify the most relevant body height dimension trait as a selection criterion for the milk yield increase program. The test animals for the study were 121 heads of Holstein cows, and seven characteristics of body height were recorded for each cow separately. Principal component analysis (PCA), correlation, and regression were used to analyze the data. As an analytical tool, the R program 4.2.1 with RStudio was employed. The primary elements discovered in PCA's output were the wither height (WTH), back height (BCH), rump height (RMH), thurl height (TLH), tail-head height (THH), and pins height (PNH). Afterward, the correlation and regression analysis findings showed that the rear udder height (RUH) had the highest priority in correlating with milk yields, followed by the thurl height (TLH). In conclusion, it is proposed that the RUH be utilized for the cow selection scheme while the TLH is used for the calf and heifer selection programs.

Introduction

Generally, taller cows produce more milk than shorter cows (42). Meanwhile, dairy cattle have various linear traits related to body heights, such as wither height (43), back height (31), rump height (43), tail-root height (40), pin bone height (19), thurl height (53), and rear udder height (45). Therefore, this is considered a large number of parameters to be executed in the selection program for dairy cattle.

It is challenging to investigate this matter since dairy cattle have a significant share of the dimensional variable of body height. It necessitates excessive time, energy, and a research budget to identify dairy cattle's body height's most essential linear traits. The principal component analysis (PCA) method can address those problems. An article explained that principal component analysis could reduce the number of characteristics that should be assessed for milk production and composition and make an essential contribution to data quality by explaining the characteristics of Holstein cows (1).

The canvas of this topic could be more varied nowadays. Indeed, the protruding body height of cows concerning milk yield is still labeled equivocally and unconfidently. Such exploration only revealed the significant contribution of height regions of Rhodope Shorthorn cows to growth performance; meanwhile, milk capacity needs to be improved (30). Another study merely analyzed the relation of the height dimension to daily milk production (37). Briefly, the prime body height to milking potency information is inadequate; thus, the selection program lacks impracticality and is uneconomical, particularly for small-scale farms. Consequently, this theme should be delved into shortly.

Additional analyses of Pearson's correlation and regression analysis are used to capture the level of association between body height traits and milk yields, like a study done by American investigators on the relationship between body size and milk supply potency to recognize the supreme height frame structure (24). As a result, dairy cattle's superior body height and linear features could be firmly established over time. The current study proposes a substantial body height feature as a selection criterion based on the degree of correlation with milk yield to address this issue.

Materials and Methods

Data compilation: In terms of execution, this exploration was completed using 121 Friesian Holstein cows on a commercial dairy farm, namely UD. Saputra Jaya, East Java, Indonesia. Also, the sample age range was 2–6 years old, and the cows were entirely in the lactation period. Then, entire body height variables were measured using a cattle stick gauge with a centimeter (cm) scale so that the data was of the interval data type. Body height variables and their detailed descriptions are displayed in Table 1.

Statistical Analysis: Regarding data analysis, R application type 4.2.1 with RStudio was applied to perform principal component analysis (PCA), correlation, and regression analysis alternately. Then, the mathematical model of the PCA is as follows:

$$\mathrm{PC}_i = \beta_{i1}\mathrm{X}_1 + \beta_{i2}\mathrm{X}_2 + \beta_{i1}\mathrm{X}_1 + \beta_{i3}\mathrm{X}_3 + \cdots + \beta_{im}\mathrm{X}_m \quad (38)$$

with β_i: coefficients$i^{\text{-th}}$; X_m: variable $m^{\text{-th}}$.

Meanwhile, the formulas of correlation (a) and regression (b) are reflected as

$$r^2 = \frac{[\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})]^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2} \quad \text{(a) (46)}$$

$$Y = \alpha + \beta x + \mathcal{E} \quad \text{(b) (15)}$$

which $\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$ and $\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n}$ are the means of a sample. Then, α is the independent term, β is the slope of the straight line, and $\mathcal{E}$ is a mark of the perturbation element.

Continuing with the test interval method of milk yield ($\mathrm{MY_{tim}}$) mathematical model is as follows:

$$\mathrm{MY_{tim}} = I_0 M_1 + I_1\left(\frac{(M_1 + M_2)}{2}\right) + I_2\left(\frac{(M_2 + M_3)}{2}\right) + I_{n-1}\left(\frac{(M_{n-1} + M_n)}{2}\right) + I_n M_n$$

The $\mathrm{MY_{tim}}$ is the total milk yield estimation, and the M_1, M_2, and M_n are the 24-hour milk yield. Then, the I_1, I_2, and I_{n-1} are the days between two milking days. Henceforth, the I_0 is the interval between the start of lactation and the milking day's first recording. Meanwhile, the I_n is the interval between the last recording of the milking day and the dry time (21). Then, the milk yieldsare standardized at 305 days ($\mathrm{MY_{s305}}$), and the milk yield's mature equivalents ($\mathrm{MY_{me}}$) (28)are also determined.

Results

Table 2 shows the probe results of Holstein's body height linear traits as a descriptive statistic. WTH, BCH, RMH, TLH, THH, PNH, and RUH range scores were generally broad. The PNH trait had the most extensive data range, whereas the RUH trait had the narrowest data range. In the meantime, Table 3 emerged with the outright data of Kaiser Meyer Olkin Measures Sampling Adequacy (KMO-MSA) and Bartlett's test of sphericity. All body height features scored higher than 0.5 except for the RUH trait. Even though RUH's KMO-MSA score was only 0.12 individually, the average overall score was still above 0.5. Furthermore, Bartlett's test p-value was less than 0.01.

Table 1. Description and symbols of dairy cattle body heights

Body height	Symbols	Description	References
Withers height	WTH	Measured as the vertical distance from the top of the wither *spine* to the floor	(11)
Back height	BCH	Measured as the vertical distance from the top of the back *spine* last rib to the ground	(11)
Rump height	RMH	Measured from the anterior edge of the *sacrum* between the hips vertically when a cow was standing	(11)
Thurl height	TLH	Measured as the height at the greater *trochanter* to the floor	(35)
Tail-head height	THH	Measured from the anterior edge of the *caudal* (*sacrococcygeal* region) vertically to the floor base	(20)
Pins height	PNH	Measured as the height of pin or *tuber ischium* to the concrete	(11)
Rear udder height	RUH	Downmost point of the vulva to the uppermost point of the ligament suspensory rear-view	(10)

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Table 2. Descriptive Statistics of dairy cattle body heights and milk yields

Body height	Min	1st quartile	Median	Mean Statistic	St. error	3rd quartile	Max
WTH (cm)	120.1	128.6	132.2	133.0	0.57	136.6	152.6
BCH (cm)	117.6	128.9	132.4	133.2	0.58	137.3	151.4
RMH (cm)	121.7	128.7	132.1	132.8	0.57	136.2	151.4
TLH (cm)	90.6	104.2	108.7	108.4	0.63	112.7	125.4
THH (cm)	122.1	128.9	132.6	133.3	0.54	136.2	152.3
PNH (cm)	109.4	117.4	121.9	122.5	0.64	126.9	146.5
RUH (cm)	7.20	14.60	17.80	17.84	0.39	20.80	27.6
MY_{tim} (kg)	1789	2314	2538	2556	29.96	2729	3673
MY_{s305} (kg)	1985	2263	2448	2482	27.17	2646	3357
MY_{me} (kg)	2105	2551	2764	2809	33.77	3043	3853

WTH: wither height; BCH: back height; RMH: rump height; TLH: thurl height; THH: tail head height; PNH: pins height; RUH: rear udder height; MY_{tim}: milk lactation total of test day; MY_{s305}: the whole milk lactation 305 days; MY_{me}: the overall milk lactation matured evenly.

Table 3. KMO-MSA and Bartlett's test of dairy cattle body height

Test type								
					Score			
Kaiser-Meyer-Olkin factor adequacy (Overall MSA):					0.83			
MSA for each item:	WTH	BCH	RMH	TLH	THH	PNH	RUH
	0.88	0.84	0.79	0.93	0.79	0.81	0.12
Bartlett's test of sphericity	Chi-squared:		1122.9				
	df:		21				
	p-value:		0.001				

WTH: withers height; BCH: back height; RMH: rump height; TLH: thurl height; THH: tail head height; PNH: pins height; RUH: rear udder height.

Table 4. Eigenvector of the dairy cattle body heights principal component

Traits	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6	PC_7
WTH	0.4138	-0.3283	0.0632	-0.0153	-0.6485	0.5074	0.1967
BCH	0.4275	-0.2979	-0.0198	-0.0949	-0.2521	-0.7220	-0.3663
RMH	0.4193	-0.2852	-0.0367	-0.0844	0.5048	-0.1421	0.6778
TLH	0.3843	0.6091	-0.5295	-0.4393	-0.0514	0.0721	-0.0113
THH	0.4038	-0.1789	0.0439	0.0791	0.5045	0.4288	-0.5987
PNH	0.3992	0.5504	0.4425	0.5650	-0.0496	-0.1071	0.0933
RUH	-0.0094	-0.1270	-0.7185	0.6821	-0.0377	-0.0212	0.0221

WTH: wither height; BCH: back height; RMH: rump height; TLH: thurl height; THH: tail head height; PNH: pins height; RUH: rear udder height; $PC_{1\text{-}7}$: the principal component number one to seventh.

An important next-level consideration in the principal component analysis is the eigenvector or loading factor and Eigen value output. Tables 4, 5, and 6 give rise to the eigenvector, loading factor, and Eigen value from this investigation, respectively. However, loading factor analysis can be used for simplicity and more comprehensive dimension reduction. Table 5 details the loading factor for a primary component in this investigation. The further issue is that the early principal component (PC_1) had an explained capability of 75.4% by the total proportion of variance, as illustrated in Table 6. Furthermore, PC_2 to PC_7 only explained capabilities that begin at 8.92% and gradually decrease. THE LINEAR EQUATION OF DAIRY CATTLE BODY HEIGHT IS GIVEN because PC_1 is the only combination with a percentage of variance explained above 10%.

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$$PC_1 = 0.414\ log\ (x_1) + 0.427\ log\ (x_2) + 0.419\ log\ (x_3) + 0.384\ log\ (x_4) + 0.404\ log\ (x_5) + 0.399\ log\ (x_6)$$

with PC_1: principal component 1; x_1: wither height (WTH); x_2: back height (BCH); x_3: rump height (RMH); x_4: thurl height (TLH); x_5: tail-head height (THH); x_6: pins height (PNH) in that order.

The correlation coefficient among the body-height linear traits is given in Table 7. This table revealed that the correlation among body height linear traits was almost entirely positive; additionally, it had a relatively high association among variables. Only RUH negatively correlates with the other body height features, making it clear that RUH stands out. It also ran in parallel with the PCA output. The RMH and THH traits had the highest correlation coefficient; RUH and THH had the lowest. When body height traits were linked to milk yields, the most significant association was delivered by RUH, followed by TLH.

The regression coefficient for Table 8's linear model to predict the milk yield test interval using body height features was given as follows:

$$MYT_{1st} = 2962.059 - 22.783(x_7)$$
$$MYT_{2nd} = 2269.664 - 22.717(x_7) + 6.382(x_4)$$

While the following model is consistent with estimating milk yield at 305 days:

$$MYS_{1st} = 2884.602 - 22.565(x_7)$$
$$MYS_{2nd} = 1824.636 - 22.463(x_7) + 9.770(x_4)$$

eventually, calculating the milk yield of mature equivalents will apply to this equation

$$MYM_{1st} = 3182.516 - 20.922(x_7)$$
$$MYM_{2nd} = 1855.119 - 20.794(x_7) + 12.235(x_4)$$

MYT_{1st} Is the first formula to estimatethe milk yield test interval; MYT_{2nd} is the second formula to predict the milk yield test interval. Then, the MYS_{1st} is the first formula to compute the milk yield standardized at 305-d; theMYS_{2nd} is the second formula to calculatethe milk yield standardized at 305-d. Henceforth, theMYM_{1st} is the first formula to assess themilk yield of the mature equivalent; and theMYM_{2nd} is the second formula to evaluate the milk yield of the mature equivalent. Meanwhile, thex_4 isTLH,and thex_7 is RUH.

Again, the RUH trait is indicated as having a prominent capacity to predict milk yields according to the regression analysis stepwise method; besides, the TLH trait was also detected as an essential character in the dairy cattle body height. Hence, these two traits should be observed meticulously due to the evidence and analysis output directed at them.

Table 5. Loading factor of the dairy cattle body heights principal component

Traits	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6	PC_7
WTH	0.414	0.328			0.649	0.507	0.197
BCH	0.427	0.298			0.252	-0.722	-0.366
RMH	0.419	0.285			-0.505	-0.142	0.678
TLH	0.384	-0.609	-0.529	0.439			
THH	0.404	0.179			-0.505	0.429	-0.599
PNH	0.399	-0.505	0.442	-0.565		-0.107	
RUH		0.127	-0.718	-0.682			

WTH: wither height; BCH: back height; RMH: rump height; TLH: thurl height; THH: tail head height; PNH: pins height; RUH: rear udder height; PC_{1-7}: the principal component number one to seventh.

Table 6. Eigenvalue of the dairy cattle body heights principal component

Level	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6	PC_7
Standard deviation	14.221	4.892	4.232	4.107	1.687	1.376	0.844
Portion of Variance	0.7545	0.0892	0.0730	0.0629	0.0106	0.0071	0.0027
Cumulative Portion	0.7545	0.8437	0.9167	0.9797	0.9903	0.9973	1.0000

PC_{1-7} is the principal component number one to seventh.

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Table 7. Phenotypic correlation between dairy cattle body heights and milk yields

Corr.	WTH	BCH	RMH	TLH	THH	PNH	RUH	MY_{tim}	MY_{s305}	MY_{me}
WTH	1.00									
BCH	0.95^{**}	1.00								
RMH	0.94^{**}	0.96^{**}	1.00							
TLH	0.63^{**}	0.68^{**}	0.68^{**}	1.00						
THH	0.93^{**}	0.93^{**}	0.97^{**}	0.68^{**}	1.00					
PNH	0.68^{**}	0.67^{**}	0.67^{**}	0.63^{**}	0.75^{**}	1.00				
RUH	-0.30	-0.03	-0.02	-0.01	-0.00	-0.07	1.00			
MY_{tim}	0.09	0.11	0.07	0.14	0.08	0.11	-0.30^{**}	1.00		
MY_{s305}	0.20^{*}	0.23^{*}	0.19^{*}	0.23^{*}	0.18^{*}	0.14	-0.33^{**}	0.90^{**}	1.00	
MY_{me}	0.15	0.20^{*}	0.16	0.23^{**}	0.17	0.15	-0.24^{**}	0.73^{**}	0.85^{**}	1.00

WTH: wither height; BCH: back height; RMH: rump height; TLH: thurl height; THH: tail head height; PNH: pins height; RUH: rear udder height; MY_{tim}: milk lactation total of test day; MY_{s305}: the whole milk lactation 305 days; MY_{me}: the overall milk lactation matured evenly.
** Significantly correlated at the 0.01 degree (2-tailed).
* Significantly correlated at the 0.05 degree (2-tailed).

Table 8. Regression coefficient of body height of dairy cattle related to milk yield.

Model		Milk yield-test day (MY_{tim})		Milk yield-standardized 305d (MY_{s305})		Milk yield-mature equivalent (MY_{me})	
		β	Adj. R sq.	β	Adj. R sq.	β	Adj. R sq.
1	Intercept	2962.059	0.081**	2884.602	0.098**	3182.516	0.051**
	RUH	-22.783		-22.565		-20.922	
2	Intercept	2269.664		1824.636		1855.119	
	RUH	-22.717	0.091	-22.463	0.142*	-20.794	0.096**
	TLH	6.382		9.770		12.235	

**P-value < 0.01.
* P-value < 0.05.

Discussion and Conclusion

A comparative study with another relevant investigation was published: mature Holstein cows have a wither height (WTH) of 124–158 cm (11, 17, 23, 31, 32, 42, 48), a back height (BCH) of 116–160 cm (11, 17, 31), a rump height (RMH) of 125–162 cm (11, 17, 31), and a pins height (PNH) of 119–153 cm (9, 11, 31). Meanwhile, the range score of thurl height (TLH) is 122–130 cm (4), tail-head height (THH) is 113–121 cm (27), and rear udder height (RUH) is 21.95 cm on average (10). The range of cow's body highness data previously exposed is compiled under the minimum and maximum highness points from the manifold of cited references.

Based on the literature on the body height of dairy cattle mentioned before, this investigation is in the tolerable normal range, even though some linear traits are in the outer boundary area. The outlying data gap of the present watchfulness could be clouted by the availability of cow research samples on the farm being very heterogeneous and unhomogenized ?? from small to oversized frames of a cow. Thus, the range of data variance is broader than the references. Another factor is caused by the distinctiveness of the cattle breeds used in the present study, the excerpted quotation, and limited sources such as appeal articles on several body height properties. Wither height (WTH) correlates relatively significantly with live weight, carcass weight, and meat yield (39, 51). A positive correlation between those linear traits caused by the height of the withers correlated positively with feed intake (FI), body weight (BW), average daily gain (ADG), feed conversion ratio (FCR), and residual feed intake (RFI). However, it has a negative genetic correlation with residual gain (RG) (13). In parallel, growth in wither height is 0.120±0.002 cm/kg LW/day for Friesian-Holstein breed cows, mainly (18). However, the swiftest gains in live weight, wither relative height development, and feed cost efficiency for those traits of the calf occurred throughout the time before reaching six months of age (23). In addition, body height is considered for calculating the cubicle width, headspace, lunging space, cubicle partition, top-bottom rail, and separation wall (16). Another study in linear terms discovered that the result of PCA in the diverse body of linear traits with cubic dimensions revealed 51.4% of the

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total variability, with the first and second factors accounting for 40.2% and 11.1% of the total variability, respectively. The WTH is also classified as a significant trait in another breed of cattle by PCA (47, 50). Nonetheless, when interconnected, milk capacity is characterized as trivial (2, 33). Propitiously, this merit has a high heritability capacity (55).

Back or loin height (BCH) insignificantly and weakly correlates to trunk or relative body length (37). However, it relates to live weight significantly in Holstein and Jersey breeds (31). Quite similar to WTH, the BCH also has the profitable nature of a moderate to high heritability score (5, 29). Afterward, this feature is also highly correlated to the other highness structure of the body in the dairy cattle breed (34).Nonetheless, the evidence about this feature linked to milk yield still needs to be densely detected.

Rump or hip height (RMH) has vigorously replied to routine milk delivery volume (41). The RMH is recommended as a selection criterion in Holstein and their crossbreed at calf to heifer period (8). Another researcher also suggested that the RMH trait be applied as a sorting factor for the selection (43).The underlying logic is a very high score of heritability on this property (6, 7, 12, 54). In addition, the RMH relative to WTH could be applied as an overgrowth indicator (26).

Thurl height (TLH) could be used as a criterion to cull a cow for disposal of inabilities or disease, and the higher the TLH, the lower the probability of being culled in Holstein breeds (53). However, criticism of the thurl is more frequently emphasized on the trochanter placement or position between the hip and pin bone (3), and it has a 0.22 heritability score (36).Reasonably, a greater taper corner on the thurl “V” shape will possess a lower thurl height than the obtuse one, even though it has a tantamount highness of body.

Tail head height (THH) has a 0.25 adjusted heritability score (44). This nature is commonly connected to the parturition course, but the opposing viewpoint says the calving difficulty is not associated with tail-head or tail-root height (20). Therefore, this trait of milk delivery should be discussed more. Comparable to fettle, the height of the pin (PNH) is seldom chewed over as well. Nevertheless, an article stated that the PNH is poor, negatively correlates with the milk supply, and is insignificant (37). Vice versa, this property links to body weight significantly in Holstein and Jersey cattle breeds (31).

A study shows that the rear udder height (RUH) is significantly related to milk yields (52), but the heritability is low to moderate (25).Selection on the RUH combined with the other udder traits is given significant distinction on Holstein's predicted transmitting ability for type (PTAT) score (14). Moreover, the total milk volumes, total lactation number, and total day in milk (DIM) are leveraged simultaneously by this characteristic (22). Unquestionably, the RUH is a crucial trait for milk yield characteristics because it is a section of the udder's properties. As a note, the golden expansion period of the udder occurs in the heifer stages and is saliently influenced by environmental factors (49).

Briefly, the present outturn of the PCA, confronted with the magnitude of works of literature in the pertaining field, is signified by an imitation issuance. It is bestowed on the WTH, BCH, RMH, TLH, THH, and PNH as crucial factors in dairy cattle and eliminates the RUH. Contrarily, the correlation and regression analyses are inclined toward the RUH as the most pertinent linear trait to milk yield, followed by the TLH. Later, the WTH, BCH, RMH, TLH, THH, and PNH are outwardly closer to the growth performance characteristics than the milk capacity. Encapsulates this investigation given the confirmation that the milk yield improvement program could prioritize TLH for calves and heifers because these stages are the golden growth curve period and the RUH does not spring up yet. Meanwhile, the lactation cows should be focused on the RUH owing to the critical period of udder growth in the heifer phase. By virtue, the lactation cows have already passed through that precarious moment, and the udder structure has been steadfastly positioned and settled by now.

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Conflict of Interest

The writers stated there are no conflicts of interest. This investigation is a section concisely of Sigid PRABOWO Ph.D. thesis.

Author Contributions

Sigid PRABOWO carried out the experiments comprised planned, carried out the simulations, contributed to sample preparation, and wrote the manuscript. Prof. Dr. Mustafa GARİP contributed to the interpretation and analysis of the manuscript.

Data Availability Statement

The data supporting this study's findings are available from the corresponding author upon reasonable request.

Ethical Statement

This study was carried out after the animal experiment was approved by Airlangga University Local Ethics Committee (Decision number: 3.KE.137.12.2021).

Animal Welfare

The authors confirm that they have adhered to ARRIVE Guidelines to protect animals used for scientific purposes.

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