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SELECTION INDEXES FOR IMPROVING GROWTH RATE IN HOLESTEIN HEIFERS WITH MINIMUM CONCOMITANT INCREASE IN BIRTH WEIGHT

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SUMMARY

The aim of this paper was to improve pre and post weaning growth rates while keeping birth weight increase at minimum level to alleviate risk of dystocia. A total number of ten selection indexes were derived from data on Holstein heifers raised at an Egyptian State-owned farm, from 1988 through 1994. These data represent records of 552 progeny of 25 sires and 459 dams. The traits considered as sources of information in the indexes were birth weight (BW), weaning weight (WW), yearling weight (YW) and the average daily gains during the periods separating birth (B) from weaning (W), (DG_{B-W}), weaning from yearling (Y), (DG_{W-Y}), and birth from yearling, (DG_{B-Y}). In constructing the indexes the aggregate genotype included DG_{B-W} and DG_{W-Y}. Phenotypic and genetic parameters were estimated from a multitrait animal model where year and season of birth effects were considered as fixed and the additive direct genetic effects as random.

Selection index with BW, WW and YW (I_1) had comparable accuracy with the index including the two segmented daily gains (I_6), but with greater increase in BW, WW and YW. Excluding BW from I_1, to form I_3, resulted in an increase of 17% in BW, while accuracy and improvements in WW and YW remained the same. Ignoring both BW and WW from I_1, to form I_5, is expected to reduce the increase in BW by 0.10 kg but with reduction in the increase in WW and YW by 0.50 and 0.10 kg, respectively.

Results indicated that in case of populations where a level of increase of less than 0.7 kg in BW would be tolerated in each round of selection, the three indexes including YW, (I_1, I_3 and I_5), are recommended. However, breeders using I_5 would benefit from its being a single trait index that can be less expensive and easier to apply. In case of populations that have already reached optimal BW, restricting I_1 to form $I_{1(BW)}$, genetic gain in BW is limited to zero, but at the expense of reduction in improvement of 35% in WW and 10.5% in YW as compared with the unrestricted form (I_1).

***Keywords**: Body weights, daily gains, genetic parameters, selection indexes, Holstein heifers.*

INTRODUCTION

Egypt′s dairy cattle producers experienced that Holstein heifers of high growth performance show decreased time to conception and better milk yield during the first lactation as compared with those of low or average growth performance. Thus, it appears that a primary interest of those producers would concentrate on the improvement of pre and post weaning growth rates of their heifers without much concomitant increase in birth weight to minimize the risk of calving difficulties (Laster *et al.*, 1973).

The use of a selection index is recommended when improvement of more than one trait is desired (Hazel, 1943). The restriction of indexes has been prescribed (Kempthorne and Nordskog, 1959) whenever genetic concomitant change in one or more traits has to be kept within bounds. Yet, no reports could be found concerning selection indexes for improving growth rate for Holstein heifers in Egypt.

The objective of the present study was to construct selection indexes that maximize genetic progress towards increasing net income per g gain per day added to yearling weight with minimum increase in birth weight to alleviate risks of dystocia.

MATERIAL AND METHODS

Data

Weight-age data recorded over the period from 1988 to 1994 on 552 Holstein heifers, progeny of 25 sires and 459 dams, from a single herd belonging to the Egyptian Company for Meat and Milk Production, Fariskur, Damietta, Egypt were used to develop selection indexes for improvement of pre and post weaning daily gains.

Management and feeding

Following their birth, animals remained with their dams for 72 hours to suckle colostrum before being moved to individual pens where they were drinking milk from buckets at 7.0 a.m. and 6.0 p.m. every day. After weaning at 4 months of age, animals were housed in semi-roofed yards and fed concentrate calf mixture containing 37.5% yellow maize, 20% soybean meal, 15% corn gluten, 22.5% wheat bran, 3% molasses, 0.5% premix and 1.5% common salt. In winter, Egyptian clover (*Trifolium alexandrinum*) and in summer green maize was offered *ad. libitum*.

Traits

Body weights at birth (BW), weaning (WW) and yearling (YW) and daily gains from birth to weaning (DG_{B-W}), from weaning to yearling (DG_{W-Y}) and from birth to yearling (DG_{B-Y}) were measured on each animal. Two birth seasons (April-September and October-March) and seven years (1988-1994) were identified for each trait.

Statistical analysis

Multitrait animal model was used to analyze the six traits simultaneously using the program of Meyer (1998). The animal model in matrix notation was:

$y = Xb + Za + e$

where:

Y = the vector of observations (body weight or daily gain);
b = the vector of fixed effects (birth season and birth year);
a = the vector of random additive genetic direct effects;
X and Z = known incidence matrices relating observations to the respective fixed and random effects with Z augmented with columns of zeros for animals without records; and
e = the vector of random residual effects.

Definition of heifer holder's income

This was defined as the revenue realized by the heifer producer in terms of kg increase in yearling weight.

Definition of the true breeding value

The breeding objective was to maximize the heifer holder's income through his selection for faster pre and post weaning daily gain. The true breeding value (T) was defined as:

$$T = a_1\ g\ DG_{B\text{-}W} + a_2\ g\ DG_{W\text{-}Y}$$

where:

$g\ DG_{B\text{-}W}$ and $g\ DG_{W\text{-}Y}$ = the additive genetic value for DG (g day^{-1}) recorded during the periods separating B from W and W from Y; and

a_1 and a_2 = the relative economic weights for $DG_{B\text{-}W}$ and g $DG_{W\text{-}Y}$, respectively.

Cost of g day^{-1} growth was assumed to be the same before and after weaning. Each unit, i.e. one gram per day, increase in $DG_{B\text{-}W}$ at constant level of $DG_{W\text{-}Y}$ will add 120 g to the YW and each unit increase in $DG_{W\text{-}Y}$ at constant level of $DG_{B\text{-}W}$ will add 240 g to the YW. Thus, the contributions of $DG_{B\text{-}W}$ and $DG_{W\text{-}Y}$ to YW permits to assign relative economic values of, respectively, 1 and 2.

Selection indexes

The six traits studied were used in combinations to construct ten selection indexes (Cunningham *et al.*, 1970) grouped under three strategies as follows:

Strategy i. Selection based on body weights (i.e. BW, WW and YW);
Strategy ii. Selection based on daily gains (i.e. $DG_{B\text{-}W}$, $DG_{W\text{-}Y}$ and $DG_{B\text{-}Y}$); and
Strategy iii. Selection based on the most accurate index , given no genetic change would occur in BW.

RESULTS AND DISCUSSION

Means, Phenotypic Variation and Heritabilities

Estimates of means, phenotypic variation and heritability for body weights and daily gains are presented in Table 1. The coefficients of phenotypic variation were slightly greater for daily gains (16.3-19.9 %) than for body weights (14.7 to 15.8%).

The six traits appeared to be moderately heritable (h^2 = 0.26 to 0.39) and high enough to allow for an efficient selection for direct genetic improvement. Comparable estimates were previously reported on Holstein calves and heifers (Oudah, 2002; Sadek *et al.*, 2005), beef heifers (Bourdon and Brinks, 1982; Simth *et al.*, 1989) and beef young bulls (Koots *et al.*, 1994a).

Table 1. Estimates of means, coefficients of variation (C.V. %) and heritability (h^2) for body weights (kg) and daily gains (g per day)

Trait	Symbol	Mean	CV %	h^2
Birth weight	BW	29.4	15.8	0.37
Weaning weight	WW	91.2	15.4	0.39
Yearling weight	YW	217.3	14.7	0.31
Daily gain during the period separating:				
Birth from weaning	DG_{B-W}	515	19.9	0.32
Weaning from yearling	DG_{W-Y}	525	19.6	0.26
Birth from yearling	DG_{B-Y}	522	16.3	0.29

Correlations

Table 2 gives the phenotypic and genetic correlations between the six traits considered in construction of selection indexes.

Table 2. Genetic (above diagonal) and phenotypic (below diagonal) correlations between body weights and daily gains

	Body weight at:			Growth rate from:		
Traits	**BW**	**WW**	**YW**	DG_{B-W}	DG_{W-Y}	DG_{B-Y}
Birth, BW	….	0.65	0.34	0.34	-0.01	0.15
Weaning, WW	0.45	….	0.59	0.93	0.07	0.48
Yearling, YW	0.23	0.48	….	0.58	0.84	0.98
Daily gain during the period separating:						
Birth from weaning	0.07	0.92	0.44	….	0.09	0.53
Weaning from yearling	0.02	0.01	0.88	-0.01	….	0.89
Birth from yearling	0.05	0.41	0.98	0.44	0.90	….

Phenotypic and genetic association between the two traits in aggregate genotype

DG_{B-W} was practically independent genetically (r_G = 0.09) and phenotypically (r_P = -0.01) from DG_{W-Y}, indicating that preweaning growth contributes little to the genetic variation in postweaning growth. There is some evidence in beef heifers indicating that genes controlling pre-weaning and post-weaning daily gain are different (r_G = 0.09, Bourdon and Brinks, 1982).

Genetic association between traits in aggregate genotype and those used as sources of information

Whereas DG_{W-Y} was practically independent of WW (r_G = 0.07), it was highly positively correlated with YW (0.84). The high genetic correlations between DG_{B-W} and WW (0.93) and between DG_{B-Y} and YW (0.98) imply that the inclusion of daily gain and body weights in the same index would be of no use.

Genetic association among traits used as sources of information

Birth weight could be increased as a result of selection for heavier WW (r_G = 0.65, Table 2; 0.60, Bourdon and Brinks, 1982; 0.50, Koots *et al.*, 1994b), at yearling (r_G = 0.34, Table 2; 0.55, Bourdon and Brinks, 1982; 0.41, Smith *et al.*, 1989; 0.55, Koots *et al.*, 1994b) , or faster DG_{B-W} (r_G = 0.34, Table 2). Genetic improvement in YW seems to go along with the increase in WW as a result of the moderate genetic correlation between the two traits (r_G = 0.59).

Indexes

Selection indexes to predict the true breeding value (T) are shown in Table 3. The maximum accuracy of selection (r_{TI} = 0.55) was obtained from selection based on the index including DG_{B-W} and DG_{W-Y}. The least accuracy (r_{TI} = 0.31 to 0.37) would result from any index ignoring YW (I_2, I_4 and I_7). Whenever YW is included in the index the accuracy approaches the maximum with values ranging between 0.53 and 0.54 (I_1, I_3, I_5 and I_6). Excluding BW alone or together with WW from I_1 to form, respectively, I_3 and I_5 would essentially change nothing in accuracy. This is due to the appreciable genetic correlations recorded among BW, WW and YW (Table 2).

Table 3. Index coefficients, indexes standard deviation (σ_I) and accuracy of selection (r_{TI}) estimated from each index (I)

Index	Index coefficients*:							
	BW	**WW**	**YW**	**DG_{B-W}**	**DG_{W-Y}**	**DG_{B-Y}**	**σ_I**	**r_{TI}**
Unrestricted:								
I_1	-1.61	0.75	2.28	….	….	….	59.00	0.54
I_2	-1.39	3.01	….	….	….	….	33.08	0.31
I_3	….	0.47	2.27	….	….	….	58.70	0.54
I_4	….	2.61	….	….	…..	….	30.67	0.44
I_5	…..	…..	2.38	….	….	….	58.50	0.53
I_6	….	….	….	0.37	0.55	…	59.22	0.55
I_7	…	….	….	0.37	….	…	32.30	0.30
I_8	….	….	….	….	0.54	….	48.83	0.45
I_9	….	….	….	….	….	0.09	18.44	0.17
Restricted:								
$I_{1(BW0)}$	-4.50	0.38	2.30	….	…	….	56.99	0.53

*: for definition of symbols see Table 1.

Expected gain from use of selection indexes

Table 4 gives results of the expected change for individual traits through use of indexes with the highest accuracy (r_{TI} = 0.53 to 0.55), viz. I_1, I_3, I_5 and I_6. The use of these four indexes is expected to lead to faster growth rate with genetic change being 16 to 19 g day^{-1} between B and W, 20 to 21 g day^{-1} between W and Y, 20 g day^{-1} between B and Y and consequently, heavier WW (+2.4 to 2.7 kg) and YW (+7.3 to 7.7 kg). However, a concomitant increase in birth weight (+0.3 to 0.7 kg) would be expected from the use of these indexes and thus, could imperil ease at calving depending on the actual level of BW in the population. In case of populations with a level of BW where an increase of less than 0.7 kg in BW would be tolerated in each round of selection, the indexes including YW (I_1, I_3, I_5 and I_6) are recommendable. However, emphasis should be given to the single trait index I_5, as being from the practical stand point less expensive and easier to apply. In case of populations that have already reached optimal BW, restricting I_1 to form $I_{1(BW)}$ genetic gain in BW would be limited to zero but at the expense of reduction in improvement of 35% in WW and 10.5% in YW as compared with the unrestricted form (I_1).

Table 4. Expected genetic changes in body weights (kg) and daily gains (g/day) when using the most accurate indexes (intensity of selection = 1.0)

		Expected genetic changes in:					
Index	**Traits* involved**	**BW**	**WW**	**YW**	**DG_{B-W}**	**DG_{W-Y}**	**DG_{B-Y}**
I_1	BW, WW, YW	0.6	2.9	7.7	19	20	20
I_3	WW, YW	0.7	2.9	7.7	19	20	20
I_5	YW	0.5	2.4	7.6	16	21	20
I_6	DG_{B-W}, DG_{W-Y}	0.3	2.4	7.3	18	20	20
$I_{1(BW)}$	BW, WW, YW	0.0	1.7	6.8	14	20	19

*: see abbreviations in Table 1.

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أدلة انتخابية لتحسين سرعة النمو فى عجلات الهولستين مع أقل زيادة مصاحبة فى الوزن عند الميلاد

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كان الهدف من هذه الدراسة هو العمل على تحسين سرعة النمو مع الابقاء على الزيادة المصاحبة فى الوزن عند الميلاد عند أدنى مستوياتها تحسبا لمخاطر حدوث صعوبة فى الولادة. ولتحقيق هذا الهدف قامت الدراسة ببناء عشرة أدلة انتخابية من بيانات مأخوذة على عجلات هولستين جرى تنشئتها فى مزرعة حكومية بمحافظة دمياط خلال الفترة من 1988 إلي 1994.وقد استمدت هذه البيانات من سجلات 552 عجلة من نسل 25 طلوقة و 459 أم. أما صفات النمو التى استخدمت كمصدر للمعلومات عند بناء الأدلة الانتخابية فكانت : وزن الميلاد والوزن الفطام والوزن عند عمر سنة ومتوسط الزيادة اليومية فى وزن الجسم خلال الفترات التى تفصل بين الميلاد والفطام ، وبين الفطام وعمر سنة وبين الميلاد وعمر سنة. وأما الصفات التى تضمنتها الوراثة الكلية فكانت متوسط الزيادة اليومية فى وزن الجسم خلال الفترتين بين الميلاد والفطام وبين الفطام وعمر سنة. ولغرض بناء الأدلة الانتخابية قدرت المعالم الوراثية والمظهرية للصفات الستة المدروسة ، واستخدم كنموذج للتحليل (نموذج الحيوان متعدد الصفات Multitrait Animal Model) متضمنا التأثير المحدد لكل من موسم الولادة وسنة الميلاد والتأثير العشوائى الراجع للحيوان.

وقد أظهرت الدراسة أنه اذا جرى الانتخاب بدليل يقوم على الأوزان الثلاثة (I_1) فيتوقع أن يتم ذلك بدقة تقترب تماما من تلك المتوقعة عندما يجرى الانتخاب بدليل يقوم على صفتى متوسط الزيادة اليومية من الميلاد حتى الفطام ومن الفطام حتى عمر سنة (I_6). أما التحسين فى وزن الجسم عند الميلاد وعند الفطام وعند عمر سنة فيتوقع أن يكون أعلى باستخدام (I_1) عنه باستخدام (I_6).

كذلك أوضحت الدراسة أن استخدام الدليل I_3 (الناشىء عن حذف الوزن عند الميلاد من I_1) بدلا من I_1 يتوقع أن يسفر ذلك عن زيادة طفيفة فى الوزن عند الميلاد (0.1 كجم) دون أن يعترى تغيير دقة الانتخاب أو مقدار التحسين فى الوزن عند الفطام أو عند عمر سنة. أما اذا استخدم الدليل I_5 (الناشىء من حذف كل من الوزن عند الميلاد وعند الفطام من I_1) بدلا من I_1 فان المتوقع هو حدوث خفض قدره 17% فى الزيادة فى الوزن عند الميلاد ولكن سيكون ذلك على حساب خفض فى التحسين المتوقع فى الوزن عند الفطام (0.5 كجم) والوزن عند عمر سنة (0.1 كجم).

وقد خلصت الدراسة الى أن فى حالة العشائر التى لايزال الوزن عند الميلاد أقل من الوزن الأمثل يوصى باستخدام أى من الأدلة الانتخابية الثلاثة التى تشتمل على الوزن عند عمر سنة (I_1, I_3, I_5) حيث لايتوقع مع أى منها زيادة أعلى من 0.7 كجم فى الوزن عند الميلاد فى كل جولة انتخاب. هذا مع ضرورة الاشارة الى تفضيل المربين للدليل I_5 باعتباره دليلا احادى الصفة استخدامه أقل فى التكلفة وأسهل فى التنفيذ. أما فى حالة العشائر التى وصلت فعلا الى المستوى الأمثل من الوزن عند الميلاد فان تقييد الدليل الانتخابى I_1 لبناء نسخة المقيدة $I_{1(BW)}$ يترتب علية عدم حدوث أى زيادة فى الوزن عند الميلاد ، ولكن بتكلفة تتمثل فى خفض واضح فى التحسين المتوقع فى الوزن عند الفطام 35% وعند عمر سنة (10.5%) مقارنة بالنسخة غير المقيدة من هذا الدليل (I_1).