Paper

Financial aspects of veterinary herd health management programmes

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Veterinary herd health management (VHHM) programmes have been shown to be economically effective in the past. However, no current information is available on costs and benefits of these programmes. This study compared economics and farm performance between participants and non-participants in VHHM programmes in 1013 dairy farms with over 40 cows. Milk Production Registration (MPR) data and a questionnaire concerning VHHM were used. Based on the level of participation in VHHM (as indicated in the questionnaire), costs of the programmes were calculated using a normative model. The economic value of the production effects was similarly calculated using normative modelling based on MPR data. Participants in VHHM had a better performance with regard to production, but not with regard to reproduction. Over 90 per cent of the VHHM participants were visited at least once every six weeks and most participants discussed at least three topics. In most farms, the veterinarian did the pregnancy checks as part of the VHHM programmes. There was a benefit to cost ratio of about five per cow per year for VHHM participants, and a mean difference in net returns of €30 per cow per year after adjusting for the cost of the programme. This portrays that participation in a VHHM programme is cost-efficient. There is, however, much unexplained variation in the net returns, possibly due to diverse approaches by veterinarians towards VHHM or by other factors not included in this analysis, like nutritional quality or management abilities of the farmer.

Introduction

Veterinary herd health management (VHHM) programmes are meant to support herd health and farmers' income (Brand and Guard 1996). They were introduced in the Netherlands in the 1970s (Sol and Renkema 1984) and at present many veterinarians provide them to farmers. VHHM comprises a basic structure of goal setting, planning, execution and evaluation. Farms are visited every four to six weeks, where the veterinarian inspects the animals, evaluates gathered data and provides advice (Brand and Guard 1996). Ideally, VHHM combines animal health, food safety, animal welfare and public health with farm management and economics (Noordhuizen and Wentink 2001, LeBlanc and others 2006). VHHM programmes are used not only in the Netherlands, but on a wider scale, for instance in the UK (Wassell and Esslemont 1992) and Denmark (Kristensen and Enevoldsen 2008).

The farmers in Europe have to produce under strict, often expensive and laborious, regulations while competing with commercial farmers outside the EU who are not subjected to the same rules (Cannas de Silva and others 2006). As dairy farmers strive for further efficiency in production, driven by market economics, the risks and consequences of poor health and suboptimal production increase (Sibley 2006). VHHM programmes are meant to help farmers to produce products of high quality for a low cost price (Brand and Guard 1996). Its primary objectives include the optimisation of herd health, productivity, quality of products and profitability of the dairy enterprise (Blood and others 1978).

In practice, some farms or veterinarians embrace the concepts of VHHM by active participation, while others do not (Derks and others 2012). Also, veterinarians are not always able to meet farmers' requirements for VHHM (Hall and Wapenaar 2012, Derks 2013). Its efficiency is hard to determine. There is, for instance, no recent information on the cost implications of this programme with regard to perceived profitability in farms. A limited number of controlled studies were carried out in the early 1970s and 1980s to evaluate the effects of VHHM on farm performance (Williamson 1980, Sol and others 1984). It was shown that a VHHM programme produced considerable benefits to participating farmers. A follow-up study showed approximately 8 per cent increase in margin per cow compared with the initial margin, using 1974–1975 as a base year (Hogeveen and others 1992). Since that time, no economic studies were carried out on the effects of these programmes.

This study evaluates the economic relationship between participation in a VHHM programme and farm performance on dairy farms and estimates the costs incurred by the participation in this programme as well as the net returns (NR), including factors that influence the NR on a farm.

Materials and methods

Data collection and preparation

In total, 5000 farms in the Netherlands, having at least 40 milking cows and participating for over two years in the Milk Production Registration (MPR) by CRV BV (Arnhem, The Netherlands), were

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randomly selected. Farmers were approached by CRV BV by mail with the request to cooperate with the questionnaire and it was later sent to them via email after being pretested (Derks and others 2013). In the questionnaire, farmers were asked several questions including whether they participated in a VHHM programme or not, and if they did, which topics of VHHM were discussed with what frequency (Table 1).

For each of the responding farms, relevant data at farm level were obtained from the CRV database. They included: number of cows, production data (milk yield, percentages of fat and protein, mean days in milk and mean days dry), reproduction data (calving interval, percentage non-return at 56 days (NR56; for cows and heifers), age at first calving), herd health data (mean somatic cell count (SCC), percentage high SCC and percentage new SCC), culling data (age at culling and culling rate) and estimated NR (NRmilk). The NR56 in cows or heifers is defined as the proportion of cows or heifers that are not re-inseminated within 56 days after the last insemination, which is calculated based on the insemination data recorded. The estimated NRmilk is a multiplication of the lactational production of milk, fat and protein with an economic value. The economic values consist of the returns for milk, fat and protein, corrected for (normative) feed costs and are €–0.05, €3.25 and €4.58, respectively, for milk, fat and protein. No other variable costs besides feed costs were taken into account because we were working with the marginal NR when the milk production per cow per year is higher. These marginal returns are mainly caused by milk returns and feed costs.

Descriptive statistics and data preparation

The farm level data were summarised for participants and non-participants in VHHM. Their means were compared using independent sample t tests and data were further explored to see if there were any associations between the various parameters. Subgroup analysis of the data of the VHHM group was done to evaluate the different activities and participation levels within the VHHM programme based on responses from the questionnaire.

Data were prepared for further multivariate analysis. First, three categories were created for farm size with the following thresholds: <70 dairy cows (small), 70–120 cows (medium) and >120 (large). Secondly, the number of veterinary visits (Nv) was categorised into every week (52 visits per year), every two weeks (26 visits per year), every three weeks (17 visits per year), every four weeks (13 visits per year), every six weeks (8 visits per year) and less than every six weeks (recorded this as six visits per year). Thirdly, the number of topics that were discussed during farm visits (Nt) was determined. Finally, normative values for number of pregnancy checks (Np) were assigned to farms based on their average calving interval (in days). Farms with average calving intervals ranging between 0 and 365.5, 366 and 415.5 and 416 and 642 were assigned with 1, 2 and 2.5 pregnancy checks (per cow per year), respectively. Normative values for frequency of pregnancy checks (Pf) were assigned to farms based on their responses in the questionnaire. Farms which ticked options 'Always', 'Regular', 'When problems arise' and 'Never' were assigned 1, 1, 0.5 and 0 as Pf, respectively. It was assumed that there was no a big difference between 'always' and 'regular'. For each of the three parameters associated with VHHM (frequency of visits, pf, number of topics discussed), their association with NRmilk was tested using the χ^2 test and, where significant, a post hoc test was done to check which groups were significantly different from each other.

TABLE 1: Questions stated in questionnaire regarding participation in VHHM

Question	Options
Are you taking part in veterinary herd health management?	Yes/no
How often is your vet on the farm for VHHM?	Every week Every two weeks Every three weeks Every four weeks Every six weeks Less than every six weeks
Which topics are discussed during VHHM?	Advice on fertility Udder health Milk production Nutrition Housing Claw health Young stock analysis of production
Please mark which option is more compatible with your farm; The veterinarian checks the cows for pregnancy	Always Regularly When problems arise Never

VHHM, veterinary herd health management

Estimating costs of VHHM and calculation of adjusted NR

The costs associated with the VHHM programme were calculated using CRV data, questionnaire data, reflection with experts on the current VHHM practices and literature. Costs for each VHHM visit were built up out of three components: (1) a basic visit costs, (2) the number and costs of pregnancy checks and (3) discussion time. The time necessary for discussion was assumed to be linearly related to the number of topics discussed. Since it is not likely that all topics will be discussed every visit, the discussion time was adjusted by multiplying it with a factor 0.8. The costs of VHHM in euros per cow per year (Cvhhm) were calculated as seen in Equation 1:

$$\frac{[\mathrm{Nv}\times\mathrm{Cv}]+\left[\mathrm{Np}\times\mathrm{Pf}\times\mathrm{Pt}\times\mathrm{Nc}\times\frac{\mathrm{Ct}}{60}\right]+\left[\begin{Bmatrix}\text{if Nt}=0,0\\ \text{if Nt}>0,\mathrm{Tt1}+(\mathrm{Nt1}-1)\times\mathrm{Tt2}\end{Bmatrix}\times\mathrm{Nv}\times 0.8\times\frac{\mathrm{Ct}}{60}\right]}{\mathrm{Nc}} \quad (1)$$

Where Nv is the number of visits per year, Cv the call-out costs (€/visit), Np the number of pregnancy checks per cow per year, Pf the frequency of pregnancy checks, Pt the time necessary for each pregnancy check (minute), Nc the number of cows, Ct the costs of veterinary time (€/hour), Nt the number of topics discussed per visit, Tt1 the time necessary to discuss the first topic (minute) and Tt2 the time necessary to discuss each additional topic (minute). Assumptions for costs and time needed can be found in Table 2.

In order to estimate as good as possible the economic effect of VHHM, the NRmilk as estimated by CRV was used as basis. Additionally, two other corrected NR were calculated: NRvhhm (NRmilk corrected for costs of VHHM, Equation 2) and NRtot (NRmilk corrected for both the costs of VHHM and the costs associated with culling, Equation 3)

$$\mathrm{NRvhhm}=\mathrm{NRmilk}-\mathrm{Cvhhm} \quad (2)$$

$$\mathrm{NTtot}=\mathrm{NRvhhm}-\mathrm{Pcul}\times\mathrm{Ch} \quad (3)$$

Where Cvhhm is the costs for VHHM, Pcul is the proportion of culled cows per year on a farm and Ch is the costs to rear a replacement heifer.

The costs of a replacement heifer (Table 2) are based upon the rearing costs (€1567) excluding costs for labour (€499) and barn (€180) (Mohd Nor and others 2012).

Sensitivity analysis

Several values of assumptions were changed to evaluate their influence on the eventual cost of VHHM per cow per year: the

TABLE 2: Assumptions to calculate the costs of VHHM based on farm data

Variable	Abbreviation	Value
Call-out costs of veterinary visit (€/visit)	Cv	30
Costs of time of veterinarian (€/hour)	Ct	120
Time necessary for a pregnancy check (minute)	Pt	2
Time necessary to discuss the first topic (minute)	Tt1	10
Time necessary for each additional topic (minute)	Tt2	5
Costs of replacement heifer (€)	Ch	888

VHHM, veterinary herd health management

NRvhhm, the NRtot and the subsequent differences between the VHHM and Non-participants in VHHM (NVHHM) groups. Initial values of Ct, Pt, Tt1 and Tt2 (from Table 2) were substituted with lower and higher values in Equation 1 to generate new values of Cvhhm per farm and then substituted in Equations 2 and 3. Minimum and maximum substitutes were Ct (100, 140 €/hour), Pt (1, 4 minute), Tt1 (5, 15 minute) and Tt2 (3, 7 minute), respectively. In addition, the model was run with all minimum values and all maximum values.

Statistical analyses

All farm data variables were tested in a univariate model for their association with NR, and those with a correlation coefficient of >0.25 were selected to be included in a multivariable model. Significant and biologically relevant predictor variables were checked for assumptions of linearity and independence of measurement. Multicollinearity was checked with tolerance and variance inflation factor (VIF) statistics. The final multivariable model was built using a general linear model with VHHM as a fixed factor and four variables as covariates: age at first calving, SCC, average NR56 and age culled.

This procedure was repeated for each of the three net return variables (NRmilk, NRvhhm and NRtot) as seen in Equation 4:

$$NR_n = \beta_0 + \beta_1 * VHHM + \beta_2 * AFC + \beta_3 * SCC + \beta_4 * NR56 + \beta_5 * AC + \in \quad (4)$$

Where NRn represents one of the three corrected returns (NRmilk, NRvhhm, NRtot), β_0 represents the estimated intercept, $\beta_{(1-5)}$ represent the regression coefficients for VHHM, age at first calving (AFC), SCC, NR56 and age at culling (AC), respectively, and ∈ is the residual.

All statistical analyses were conducted using IBM SPSS (IBM Corp Released 2011. IBM SPSS Statistics for Windows, V.20.0. Armonk, New York, USA: IBM Corp).

Results

Descriptives

From the 5000 farmers approached, 1029 filled in the questionnaires. A total of 1013 were filled in completely. The 1013 farms had an average farm size of 83 cows. In all, 42 per cent had 40–70 cows, 47 per cent had 71–120 cows and 11 per cent had more than 120 cows. Of the 1013 farms, 695 (68.6 per cent) were VHHM participants and 318 (31.4 per cent) were non-participants. A total of 211 veterinary practices were listed.

Descriptive statistics are presented in detail in the study by Derks and others (2014). The main results are summarised here. There was no difference in farm size between the VHHM and NVHHM groups (P>0.1). With regard to production data, the VHHM group had a higher milk production per cow per year, even though the NVHHM group had, on average, longer lactations and more days dry. The fat and protein content of the milk was the same in both groups, though in the VHHM group the kilogram fat and protein were higher (Fig 1). With respect to reproduction parameters, there was no difference in calving interval in both groups; however, the VHHM group had a lower age at first calving. The NR56 was lower in the VHHM group (Fig 2). The age at culling was higher in the NVHHM group while VHHM had a higher culling rate. The VHHM group had a lower SCC (Fig 3). NR per cow per year were higher in the VHHM group (VHHM €2403, NVHHM €2293).

Within the VHHM group, 189 veterinary practices were involved in VHHM programmes with 618 farms responding on the frequency of visits by their veterinarian for VHHM. Half of the farms were visited every four weeks (51 per cent), 31 per cent was visited every six weeks, 2 per cent was visited every three weeks, 3 per cent every two weeks and 11 per cent of the farms was visited less than every six weeks. Pregnancy checks were always done by the veterinarian during the programme in 71 per cent of the farms (n=623) and regularly in 14 per cent. Twelve per cent of the farms only had pregnancy checks done when there was a problem and 3 per cent never had pregnancy checks done by the veterinarian. With regard to number of topics discussed during the programme, 8 per cent discussed one topic, 13 per cent two topics, 16 per cent three, 20 per cent four, 16 per cent five, 10 per cent six topics, 7 per cent seven topics and 10 per cent eight.

In relation to NR, the farms that had pregnancy checks done by the veterinarian only when there are problems showed lower returns than farms that were checked always (p<0.01). The number of topics discussed was not associated with NR. The NR were also different between groups for number of visits. Following a post

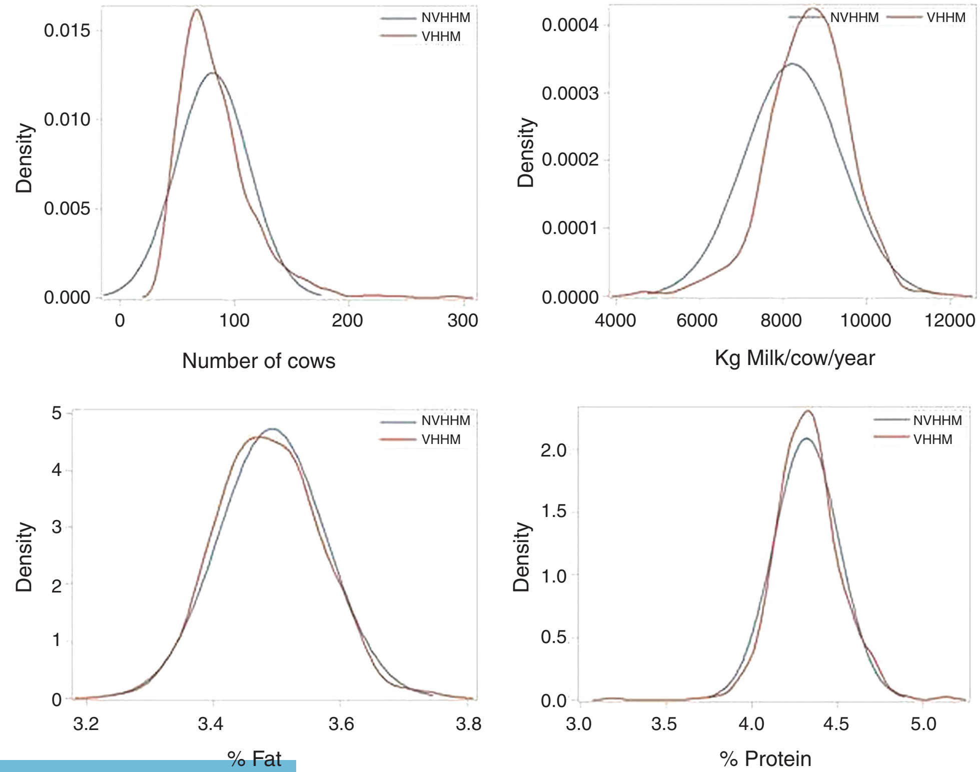

FIG 1: Kernel density plots for production variables for participants (veterinary herd health management (VHHM)) and non-participants (NVHHM) in VHHM

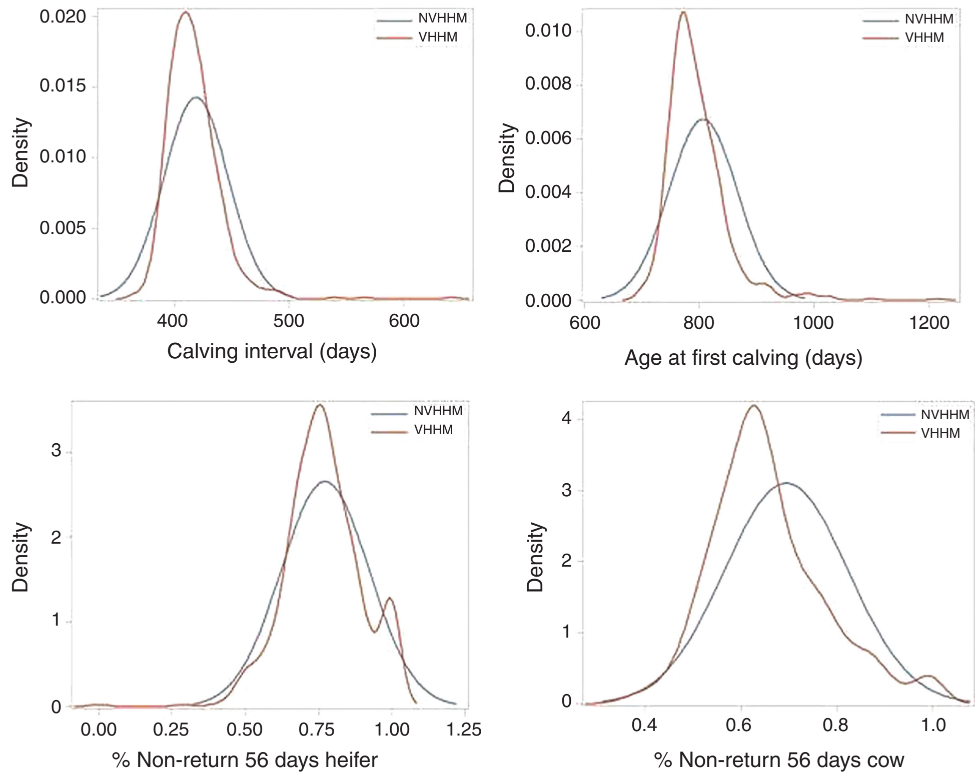

FIG 2: Kernel density plots for fertility variables for participants (veterinary herd health management (VHHM)) and non-participants (NVHHM) in VHHM

hoc test, the NR for the farms with less than six visits a year were significantly lower than those with eight visits or 13 visits a year ($p<0.01$).

Calculating costs of the VHHM programme

Table 3 shows the economic results of the VHHM and NVHHM farms for all NR scenarios. The costs of VHHM were on average €20 per cow per year. The average gains for VHHM, in terms of a higher net return for the VHHM group compared with the NVHHM group, were €95 per cow per year ($p<0.05$), resulting in a benefit to cost ratio of 4.8. When further adjusted for the costs of replacing heifers, the difference in NR between the VHHM group and the NVHHM group was €83 per cow per year ($p<0.05$), resulting in a benefit to cost ratio of 4.2.

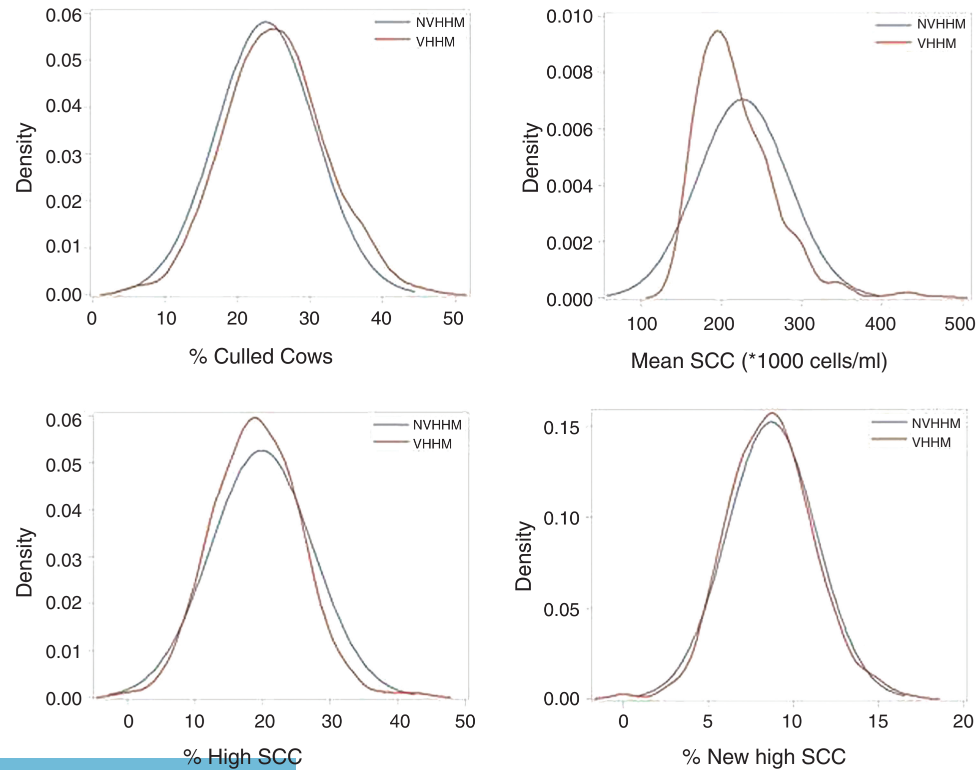

FIG 3: Kernel density plots for health variables for participants (veterinary herd health management (VHHM)) and non-participants (NVHHM) in VHHM

TABLE 3: Costs of programme and adjusted NR calculated (€/cow/year)

	VHHM			NVHHM		
	Min	Max	Mean	Min	Max	Mean
NRmilk	1452	3160	2403	1173	3066	2293
Cvhhm						
Call-out costs of vet visit	1.06	26.00	4.71	–	–	–
Cost of pregnancy check	0	10.00	8.09	–	–	–
Cost of time for discussion	0.56	40.48	6.79	–	–	–
Total	1.62	67	19.62	–	–	–
NRvhhm	1429	3138	2388	1173	3066	2293
Costs of replacement heifer	51	415	224	76	464	212
NRtot	1198	2887	2164	1018	2851	2081

All values are mean values across the groups before and after adjustment
NR, net returns; VHHM, veterinary herd health management

Sensitivity analysis

The values from the sensitivity analysis show a consistent gain in NR and adjusted NR for the VHHM group even when the time and costs of veterinary time are altered (Table 4). The mean difference in the analysis varied from €80 to €103 per cow per year for the NRvhhm, and from €68 to €92 per cow per year for the NRtot. In general, the mean values for participants did not show a large variation. The NR outcomes seemed most influenced by values were all minimum and all maximum; and among each parameter, it appeared to also be influenced more by time necessary for pregnancy check (Pt).

Multivariable model

In the three multivariate regression models created, the estimates for β in VHHM decreased with further correction of the NR. Based on the MPR data, the difference in mean NR for VHHM versus NVHHM corrected for the influence of AFC, SCC, NR56 and AC was €48 per cow per year, but in models 2 and 3, it was €30 and €28, respectively (Table 5). The effect of the VHHM programme, although positive, was only significant ($P<0.05$) in the first model.

All the covariates are negatively associated with the NR, with a reduction in NR of €261 for every per cent increase in NR56, and €1 for every extra day added to AFC. With all five variables, only 28 per cent of the variation in the NR from MPR data is explained, and after the adjustment of the NR, 24 per cent is explained.

TABLE 4: Results from sensitivity analysis

		NRvhhm		NRtot	
	Cvhhm	Mean	Mean difference (VHHM-NVHHM)	Mean	Mean difference (VHHM-NVHHM)
Basic	20	2388	95	2164	83
Ct (€/hour)					
Minimum	17	2390	97	2167	86
Maximum	22	2385	92	2162	81
Pt (minute)					
Minimum	16	2392	99	2168	87
Maximum	28	2380	87	2156	75
Tt1 (minute)					
Minimum	18	2389	96	2166	85
Maximum	21	2387	94	2163	82
Tt2 (minute)					
Minimum	18	2390	97	2166	85
Maximum	21	2386	93	2163	82
All values minimum	11	2396	103	2173	92
All values maximum	35	2373	80	2149	68

NR, net returns; VHHM, veterinary herd health management

Discussion

The response rate of 20 per cent (1013 out of 5000 farms) to the questionnaire was quite low, which may suggest response bias. Upfront, several measures were taken to prevent response bias, like introduction of the questionnaire and using the validated tailored design method (Dillman 2000). Both groups, however, had similar farm sizes, suggesting comparability of the groups.

The VHHM group produced more milk per cow per year as earlier reported in the 1970s (Sol and Renkema 1984). Even after correcting for (normative) feeding costs, this higher milk production had a major influence on the NR of a farm, despite the longer lactations observed in the NVHHM group. This may also be linked to the fact that the NVHHM group had a higher SCC which is known to be associated with a lower milk production per cow per day (Halasa and others 2009). It is possible that the NVHHM group also had a higher level of clinical mastitis, which leads to lower milk production per cow per day because of discarded milk and a lower milk production level (Halasa and others 2007). However, since we did not have data on incidence of clinical mastitis, we could not compensate for the difference in treatment costs between VHHM and NVHHM farms.

Monitoring of reproduction in dairy farms can be done in many ways, varying from examination of all cows within seven days postpartum to just pregnancy checks. It is beyond the scope of this study to examine all the different forms of fertility monitoring. In this study, the choice has been made to include the (frequency of) pregnancy checks on farms as a parameter for reproduction. Early pregnancy diagnosis can lead to a lower NR56 because the chance for re-insemination will be greater. The negative relation seen between the NR56 and NR can possibly be explained by this fact. It may also be due to other diseases or factors that need to be investigated. One of these factors includes the choice to use the NR56 and not the pregnancy rate after first insemination. The NR56 can be calculated from central databases, while the pregnancy rates have to be calculated in farm management systems. But, the latter is the most valid parameter, because in the NR56 are also included cows which are not re-inseminated, but non-pregnant. The non-difference in calving interval between the groups is contrary to what has been seen previously (Sol and others 1984), but the age at first calving is observed to approximately be the same as the national average (CRV 2011). NR56 being higher in the NVHHM group may not necessarily mean that cows were not re-inseminated because they were pregnant.

TABLE 5: Outcomes from the multivariable model with VHHM as fixed factor

	Model 1			Model 2			Model 3		
Outcome predicted	NR			NR adjusted for VHHM programme cost			NR adjusted for VHHM programme cost and cost of replacing heifer		
Parameter	β	CI	p Value	β	CI	p Value	β	CI	p Value
Intercept	4225	3993 to 4457	<0.01	4197	3954 to 4439	<0.01	3782	3541 to 4022	<0.01
VHHM (yes/no)	48.8	16.7;81	<0.01	30	−2.9 to 63.9	0.07	28	−5.1 to 61.3	0.10
AFC (days)	−1.10	−1.5 to −0.9	<0.01	−1.2	−1.5 to −0.9	<0.01	−1.2	−1.5 to −0.92	<0.01
SCC (cells/ml) (*1000)	−1.24	−1.5 to −0.9	<0.01	−1.2	−1.6 to −0.9	<0.01	−1.3	−1.6 to −1.0	<0.01
NR56 (%)	−261.7	−388 to −135	<0.01	−264	−398.9 to −129.9	<0.01	−278	−412 to −144.6	<0.01
AC (days)	−0.2	−0.3 to −0.1	<0.01	−0.18	−0.2 to −0.1	<0.01	−0.1	−0.137 to −0.021	0.01
R^2	0.28	0.27	0.24						

NVHHM is the reference category
AC, age at culling; AFC, age at first calving; NR, net returns; SCC, somatic cell count; VHHM, veterinary herd health management; *1000=multiplied by 1000

The difference in culling rate of both groups may have been a result of the veterinarian's influence to cull less productive and less healthy cows in the VHHM group. Possibly, a cow with an earlier diagnosis of a disease will be at a higher risk for culling. A lower level of disease should have led to a lower culling rate, as culling has been shown to be associated with disease (Gröhn and others 1998, Seegers and others 2003). On the other hand, at the farm level, early culling of cows with disease can lead to a lower level of disease at the farm level. Subsequent to regular pregnancy checks, and possible early diagnosis of disease, there may be a higher chance to cull animals in the VHHM group as advised by the veterinarian. In this study, it was also found that the culling rate was not related to the SCC. However, the reasons for culling are not known from the available data, so, in this study, it is not possible to make clear the influence of the veterinarian with regard to culling.

Within the VHHM group, 89 per cent of the farms get visited at least once every six weeks with only 11 per cent having less than six visits per year, which indicates a reasonable level of herd monitoring. However, the variation in the number of visits shows that there are very diverse approaches to the implementation of VHHM programmes with most farms frequently getting their cows' pregnancy status verified. Most farmers also discuss at least three topics with their veterinarians, which is expected to be beneficial.

Due to the diverse veterinary practices' approaches, estimating the average number of pregnancy checks per farm was difficult and based on assumptions. It also did not account for costs of laboratory investigations, field investigations such as diagnostic tools for scanning, prevention procedures, and costs of labour of the farmer. In Table 2, a few time variables are listed which were the basis of the calculations in this study. It is important to stipulate that these are all assumptions and merely dependent on the efficiency of the work organisation of individual farmers and vets. There will also be a difference in time needed to discuss the different topics and in the costs of time. However, from the sensitivity analysis we can conclude that the effects of this change were only small, and so these costs do not appear to be very important for the outcome.

In general, the gains of a VHHM programme are expected to be a higher milk production, lower disease levels and better reproduction. Because the variable NRmilk is based on the milk production (kilogram milk, fat and protein), it contains all effects of VHHM on milk production. Moreover, it takes the variable costs associated with a higher (or lower) milk production also into account. Therefore, we did not have to add variable costs into our model. Those variable costs that are associated with milk production were in the NRmilk, while other variable costs could be assumed to be equal for both the VHHM farms as the non-VHHM farms. This difference in milk production might be caused by a higher feed efficiency and a higher milk production due to less production diseases and a decreased calving interval. Studies on costs of disease have shown that most of the costs of disease are in milk production losses and culling. These two factors were implicitly taken into account in this study because we knew the overall milk production level and culling rate. Costs of treatments and farmers' labour were not taken into account because we did not have data on the incidence of diseases which are needed to estimate the treatment and labour costs. This might have led to an underestimation of the net effect of VHHM. Finally, a better reproductive performance can be found back in sales of calves, a higher milk production per cow per year and less culling. As with diseases, the milk production and culling effects are taken care of by the NRmilk and the culling rate. The number of calves should be taken into account separately. Because there was no significant difference in calving interval between the VHHM farms and the non-VHHM farms (Derks and others 2014), we assumed there was no difference between the generated value of calves (retained or sold) between the VHHM and non-VHHM farms.

The total costs of disease consist of failure costs and expenditures for prevention (McInerney 1992, Hogeveen 2010). In our estimations, we have covered most of the failure costs. We have no information on the expenditures for prevention. In our comparison, we assume that the VHHM and NVHHM farms have equal expenditures for prevention such as hygiene and vaccinations. It is not unexpected that VHHM farms have more preventive measures in place than NVHHM farms. This might have led to an overestimation of the effect of VHHM.

Older studies have shown that the benefits of the VHHM exceed the costs (Blood and others 1978, Sol and Renkema 1984, Hogeveen and others 1992) although specific proof of this relationship in many circumstances was difficult (Brand and Guard 1996). So, this study is the first more recent study on VHHM with a focus on economics.

Expected high costs, expected low returns and expectation in terms of time consumption were important reasons for farmers to not participate in VHHM (Derks and others 2012). However, this study has shown that VHHM participants have, on average, higher return of €4.20 for every euro spent on the programme, which is a worthwhile venture. Moreover, with increasing societal demand for milk being produced from health and happy cows, it is good to know that with the application of VHHM farms might have more healthy animals in combination with a higher NR. Even if the costs and benefits of VHHM would be equal, it is advisable to get these systems in place, because at that moment farmers would better meet societal demands at no net costs.

As expected, the influence of VHHM programmes on NR reduced as they were adjusted for the costs of replacement heifers since VHHM participants had a higher culling rate. However, the other covariates showed negative relationships with the NR, and these were higher in the NVHHM group. With only 24–28 per cent of the variation of the NR being explained by this parameter, there is once again proof that the eventual production rate is influenced by many more factors which have not been included in this study. With NR56, having such an impact on the NR, it may be that the farmers in the NVHHM group were saving on re-insemination but losing in milk production. One still cannot link this to the similar calving intervals still observed in the two groups.

There are several limits to a cross-sectional study of this nature as we cannot conclude on causality, and so we will have to reason about causality. The challenge with this study though is identifying a causal relationship as these data were based on a two-year record without information on when the VHHM farms started participating in the programme. It would also be important to know how much milk has been delivered in a life cycle of the cows especially that of the culled cows to see if this influenced the results of the production output. In most current data concerning herd health management programmes, often the economics is lacking and taking a look at the normative was considered a good start for this study. In a more extensive evaluation, book keeping data for more economic data rather than technical data would be insightful.

Conclusions

Participation in a VHHM programme is related to a higher milk production (kg/cow/year) of farms and consequently a higher NR. Even when the net return was corrected for the costs of the VHHM programme and the higher costs of replacement heifers on VHHM farms, the benefit to cost ratio was positive: 4.2 euros per euro spent for the cost of the programme which makes it cost efficient. However, participation in VHHM does not significantly predict the NR of a farm and with the current dataset causality cannot be proved.

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References

BLOOD, D. C., MORRIS, R. S., WILLIAMSON, N. B., CANNON, C. M. & CANNON, R. M. (1978) A health program for commercial dairy herds. *Australian Veterinary Journal* 54, 207–215

BRAND, A. & GUARD, C. L. (1996) Principles of Herd Health and Production Management Programs. Herd Health and Production Management in Dairy Practice 1.1, 3–14. Wageningen, The Netherlands: Wageningen Publishers

CANNAS DE SILVA, J., NOORDHUIZEN, J. P. T. M., VAGNEUR, M., BEXIGA, R., GELFERT, C. C. & BAUMGARTNER, W. (2006) Veterinary dairy herd health management in europe constraints and perspectives. *Veterinary Quarterly* 28, 23–32

CRV, A., THE NETHERLANDS. (2007) CRV year statistics 2011. (2011). https://www.cr-delta.nl/servlets/dbupload?id=11696
DERKS, M. (2013) Veterinarian awareness of farmer goals and attitudes to herd health management in the Netherlands. *The Veterinary Journal* **198**, 224
DERKS, M., VAN DE VEN, L. M. A., VAN WERVEN, T., KREMER, W. D. J. & HOGEVEEN, H. (2012) The perception of veterinary herd health management by Dutch dairy farmers and its current status in the Netherlands: a survey. *Preventive Veterinary Medicine* **104**, 207–215
DERKS, M., VAN WERVEN, T., HOGEVEEN, H. & KREMER, W. D. J. (2013) Veterinary herd health management programs on dairy farms in the Netherlands: Use, execution, and relations to farmer characteristics. *Journal of Dairy Science* **96**, 1623–1637
DERKS, M., VAN WERVEN, T., HOGEVEEN, H. & KREMER, W. D. J. (2014) Associations between farmer participation in veterinary herd health management programs and farm performance. *Journal of Dairy Science* **97**, 1336–1347
DILLMAN, D. A. (2000) Mail and Internet Surveys the Tailored Design Method. New York: John Wiley & Sons
GRÖHN, Y. T., EICKER, S. W., DUCROCQ, V. & HERTL, J. A. (1998) Effect of diseases on the culling of Holstein dairy cows in New York state. *Journal of Dairy Science* **81**, 966–978
HALASA, T., HUIJPS, K., ØSTERÅS, O. & HOGEVEEN, H. (2007) Economic effects of bovine mastitis and mastitis management: a review. *Veterinary Quarterly* **29**, 18–31
HALASA, T., NIELEN, M., DE ROOS, A. P. W., VAN HOORNE, R., DE JONG, G., LAM, T. J. G. M., VAN WERVEN, T. & HOGEVEEN, H. (2009) Production loss due to new subclinical mastitis in Dutch dairy cows estimated with a test-day model. *Journal of Dairy Science* **92**, 599–606
HALL, J. & WAPENAAR, W. (2012) Opinions and practices of veterinarians and dairy farmers towards herd health management in the UK. *Veterinary Record* **170**, 441
HOGEVEEN, H. (2010) Sensors and clinical mastitis—The quest for the perfect alert. *Sensors* **10**, 7991
HOGEVEEN, H., DYKHUIZEN, A. A. & SOL, J. (1992) Short- and long-term effects of a 2 year dairy herd health and management program. *Preventive Veterinary Medicine* **13**, 53–58
KRISTENSEN, E. & ENEVOLDSEN, C. (2008) A mixed methods inquiry: How dairy farmers perceive the value(s) of their involvement in an intensive dairy herd health management program. *Acta veterinaria scandinavica* **50**, 50.
LEBLANC, S. J., LISSEMORE, K. D., KELTON, D. F., DUFFIELD, T. F. & LESLIE, K. E. (2006) Major advances in disease prevention in dairy cattle. *Journal of Dairy Science* **89**, 1267–1279
MCINERNEY, J. P. (1992) A framework for the economic analysis of disease in farm livestock. *Preventive Veterinary Medicine* **13**, 137
MOHD NOR, N., STEENEVELD, W., MOURITS, M. C. M. & HOGEVEEN, H. (2012) Estimating the costs of rearing young dairy cattle in the Netherlands using a simulation model that accounts for uncertainty related to diseases. *Preventive Veterinary Medicine* **106**, 214–224
NOORDHUIZEN, J. P. T. M. & WENTINK, G. H. (2001) Developments in veterinary herd health programmes on dairy farms: a review. *Veterinary Quarterly* **23**, 162–169
SEEGERS, H., FOURICHON, C. & BEAUDEAU, F. (2003) Production effects related to mastitis and mastitis economics in dairy cattle herds. *Veterinary Research* **34**, 475–491
SIBLEY, R. (2006) Developing health plans for the dairy herd. *In Practice* **28**, 114
SOL, J. & RENKEMA, J. A. (1984) A three year herd health and management program on thirty Dutch dairy farms. I. objectives, methods and main results. *Veterinary Quarterly* **6**, 141–148
SOL, J., STELWAGEN, J. & DIJKHUIZEN, A. A. (1984) A three year herd health and management program on thirty Dutch dairy farms. *Veterinary Quarterly* **6**, 149–157
WASSELL, T. & ESSLEMONT, R. (1992) Survey of the operation of dairy herd health schemes by veterinary practices in the united kingdom. *Veterinary Record* **130**, 260–263
WILLIAMSON, N. B. (1980) The economic efficiency of a veterinary preventive medicine and management program in victorian dairy herds. *Australian Veterinary Journal* **56**, 1–9