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Original

Repeatability of Milk Yield in Gyr–Holstein Crossbreds under Tropical Conditions

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ABSTRACT

Background: Climate change has intensified heat stress and reduced forage productivity, negatively affecting milk production in the tropics. In Panama, the use of Gyr cattle and their crosses with Holstein aims to obtain a biotype that is more resilient and efficient. **Aim**. To estimate the repeatability of milk yield in Gyr–Holstein genetic groups under tropical conditions. **Methods:** The production farm was located in the Cañazas District, Veraguas Province, Panama. A total of 2,642 weekly milk-yield records from 62 Gyr–Holstein cows that calved between August 2020 and December 2024 were analyzed. Lactations longer than 365 days were excluded and data were expressed as weekly values. A generalized linear mixed model for repeated measures was fitted including fixed effects of year–month of calving and parity, and a random animal effect modeled with a second-order Legendre polynomial. **Results:** Milk yield followed a typical lactation curve, peaking between weeks 7 and 8 and then declining. Repeatability of yield across lactation ranged from 0.690 to 0.710. High correlations were observed between adjacent test-day records ($r \approx 0.85$), indicating good precision for identifying the best and worst animals. **Conclusions:** Differences in production merit (PM) among animals, exceeding 2,000 kg of milk over a 305-day lactation, reflect strong performance of Gyr × Holstein crosses and indicate their economic interest for breeders. Keywords. correlation; production merit; milk yield; selection (*Source*: *AGROVOC*).

INTRODUCTION

Dairy farmers and milk producers in tropical regions face mounting challenges due to climate change, such as increased heat stress and drought. These factors reduce pasture productivity, decrease the availability of nutritious feed, and raise the energy costs associated with feeding livestock. In addition, high temperatures lower animal performance and favor the proliferation of

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parasites and pathogens, thereby compromising the efficiency of production systems (Ortiz *et al*., 2018).

In this context, dairy farming requires strategies to select animals that maintain efficient production without compromising reproductive capacity under extreme heat (Vinet *et al*., 2024). Brito *et al.* (2021) suggest that preserving genetic diversity and using locally adapted breeds is a more sustainable strategy than implementing improvement programs based on temperate-climate breeds. Recent studies show that the Holstein breed in Panama retains genetic variability for milk production and heat tolerance (Guerra Montenegro *et al*., 2019), and that heterosis in crosses with *Bos indicus* improves key reproductive traits (Vargas-Leitón *et al*., 2024). In this regard, the repeatability coefficient, as described by Falconer and Mackay (1996), is a fundamental measure that indicates how consistent an animal's performance is across different lactations. Moreover, it provides a preliminary estimate of each individual's genetic potential by accounting for differences in animal performance due to additive and non-additive genetic effects as well as permanent environmental effects relative to total variation. It should not be interpreted as a genetic parameter, although it can be highly useful as an auxiliary tool for breeders (Guerra and Menéndez Buxadera, 2020).

In Panama, Gyr × Holstein genetic groups have attracted growing interest due to their strong performance under tropical conditions. However, few studies have examined in detail their milk productivity and the impact of crossbreeding on productive and reproductive parameters. Moreover, pedigree traceability in many herds is limited, which hinders accurate evaluations.

In response to this need, the present study aims to estimate the repeatability of milk yield in Gyr–Holstein genetic groups under tropical conditions, to provide key information to guide selection and genetic-improvement programs in Panama's production systems.

MATERIALS AND METHODS

Location

The production unit where this study was carried out is located in the Cañazas District, Veraguas Province, Republic of Panama, at geographic coordinates 8.3177° N, 81.1718° W. The site lies at an altitude of 174 meters above sea level and is characterized by a humid tropical climate. Average microclimatic conditions in the area include a mean daily temperature of approximately 27 °C and an average relative humidity of 80 %.

Animals-handling

The herd comprised female cattle resulting from Gyr–Holstein crosses. Their diet was based on pastures such as *Urochloa decumbens*, *Urochloa humidicola*, and *Urochloa brizantha* cv. Marandú. During milking, cows received a concentrate supplement containing 18% crude protein (CP), administered at 2–3 kg per cow depending on milk yield. Animals were milked twice daily

using mechanical milking, and milk yields were recorded starting on the fifth day of production postpartum.

Database:

Lactation records were obtained from the DelPro Farm Manager program (DeLaval, 2024). All data were consolidated into an Excel spreadsheet to create a dataset containing the animal identification number, date of birth, calving dates, age at calving in months, breed composition, number of lactations, days in milk, total milk production, and production adjusted to 305 days.

Statistical analysis

For this study, a total of 2,642 periodic test-day (TD) records from 62 Gyr–Holstein cows that calved between August 2020 and December 2024 were finally available. TD records corresponding to lactations longer than 365 days were removed. The remaining data were expressed as weekly values (dim7), which allowed for a better distribution. A generalized linear mixed model for repeated measures was fitted using the Echidna software (Gilmour, A.R., 2021), including the effects of the year–month of calving (45 levels), parity (3 classes), and a random cow effect (62 animals); the mathematical model is as follows:

$$\boldsymbol{Y_{ijkl} = \mu + A_i + P_j + C_k + e_{ijkl}}$$

Where:

$\boldsymbol{Y_{ijkl}}$**:** Weekly milk yield observed for cow l in year–month of calving i, parity j, and lactation week k.

μ: Overall mean

$\boldsymbol{A_i}$**:** Fixed effect of year–month of calving (45 levels).

$\boldsymbol{P_j}$:Fixed effect of parity (3 classes).

$\boldsymbol{C_k}$**:** Random effect of cow (62 animals), modeled with a second-order Legendre polynomial.

$\boldsymbol{e_{ijkl}}$**:** Random error associated with each observation.

The evolution of the dim7 values throughout lactation was modeled using a second-order Legendre polynomial. Repeatability (Rep) was estimated using the classical formula:

$$\boldsymbol{Rep = \frac{\sigma^2_{cows}}{\sigma^2_{cows+\sigma^2_{residual})}}}$$

where the numerator is the estimated between-cow variance, which includes permanent genetic and permanent environmental effects, and the model's residual variance is added to the denominator.

RESULTS AND DISCUSSION

All effects included in the model were highly significant ($p < 0.001$), confirming the important influence of these factors on variation in milk yield. The least-squares coefficients for the effect of dim7 on milk yield are shown in Figure 1, displaying the typical lactation curve with peak values at 7–8 weeks of lactation followed by a gradual decline.

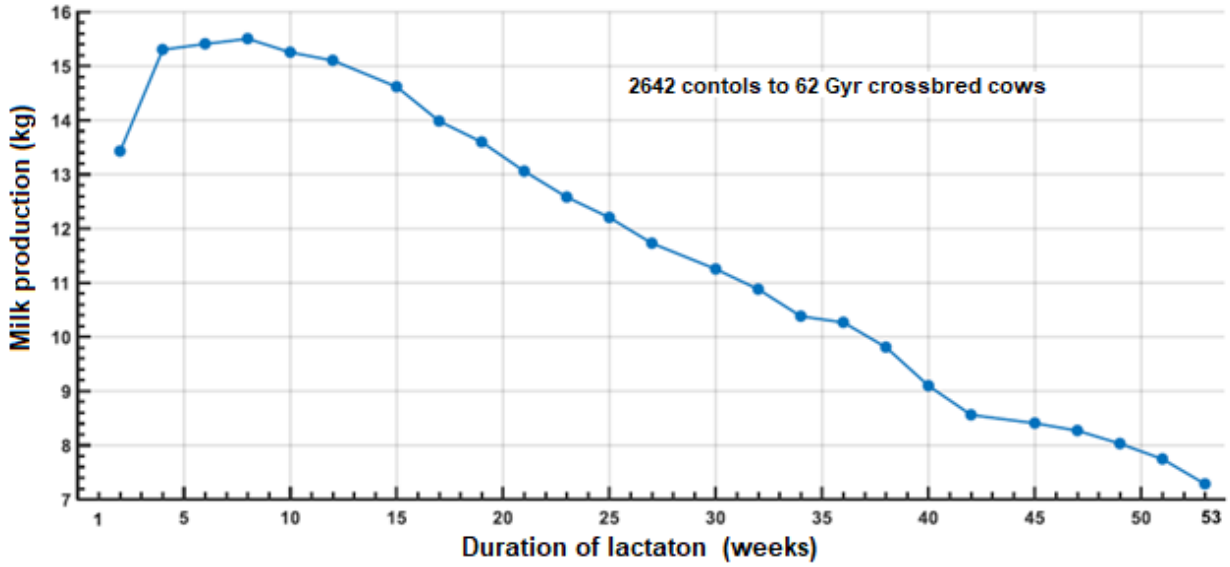

Figure 1. Lactation curve of Gyr–Holstein animals

The repeatability coefficients estimated throughout lactation ranged from 0.690 to 0.710, as shown by the blue line in Figure 2. Previous studies have reported repeatability coefficients of 0.56 for milk yield in dual-purpose cows in Venezuela (Bastidas *et al*., 2019); 0.51 and 0.76 in Gyr dairy cows in Brazil (Balieiro *et al*., 2000; Napolis *et al*., 2005; Pereira *et al*., 2021); and 0.577± 0.02, 0.675±0.02 and 0.628±0.01 in crossbreds of Brown Swiss, Jersey, and pure Holstein animals in Panama, respectively (Guerra & Menéndez Buxadera, 2020).

The estimate of productive merit (PM) is a function of each animal's deviation from the effects included in the model and the coefficients of the Legendre polynomial weighted by the trait's repeatability level. The repeatability coefficients obtained (see Figure 2) indicate adequate precision in the estimation of animals' productive merit (PM), which facilitates decision making regarding the culling of cows based on their initial milk-production records. It is important to emphasize that this process does not imply genetic selection, but an individual evaluation based on productive performance expressed over the lactation trajectory, and that the repeatability values suggest that heritability could reach moderate to high levels, since repeatability—by including both genetic and permanent environmental influences—represents a value equal to or

greater than heritability (Falconer and Mackay, 1996). This indicates that, with larger databases and complete pedigree records, it would be possible to implement genetic models that optimize selection and improvement of herds under tropical conditions.

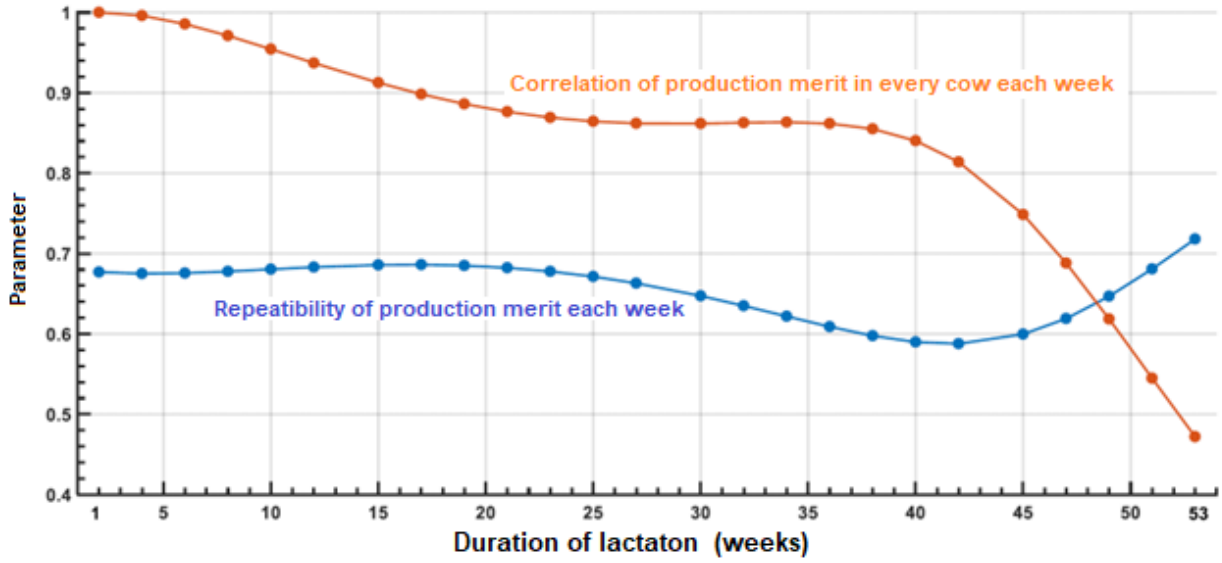

Figure 2. Estimate of repeatability of milk production and the correlation between the first test and each subsequent test

A high correlation ($r \approx 0.85$) was observed between the first test and subsequent records, indicating that initial production can predict future productive performance of the animals with good accuracy. However, the repeatability coefficient, which reflects the consistency of production from week to week, shows a gradual decline beginning at week 25. This suggests that, although initial production is a good indicator of overall performance, lactation persistency tends to decrease toward the end of the second third, reducing predictive ability in the final stages (Figure 2).

Figure 2 also suggests that there are very few changes in the shape of the production curve throughout lactation. In this context, a principal component analysis of the correlation matrix facilitates the interpretation of these patterns, the results of which are presented in Figure 3.

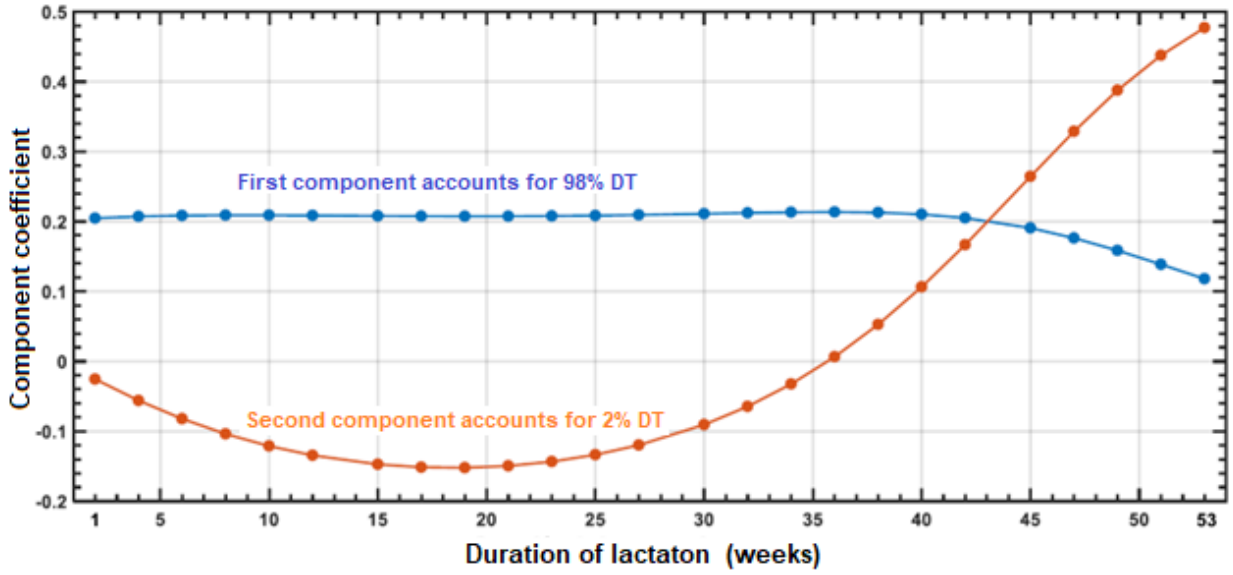

Figure 3. Evolution of the first and second principal components of the correlation matrix among all test-day records

The trends clearly show that 98% of the variation is contained in the first principal component, so the animals represented in the studied sample exhibited excellent persistency and only minor variations after 315 days of lactation. In this regard, Pereira *et al*. (2021) reported that the correlation between the breeding value for initial production level and the breeding value for persistency is r=0.57, indicating a certain relationship between the two traits. However, this relationship is not perfect, since the correlation of the linear regression coefficient with production on different test days ranged from -0.07 to 0.38, suggesting that this parameter has a limited influence on lactation persistency and total production on the test day (TD).

The low influence of lactation persistency on the total amount of milk produced on the test day could explain the substantial variability observed in the studied sample, as shown in Figure 4.

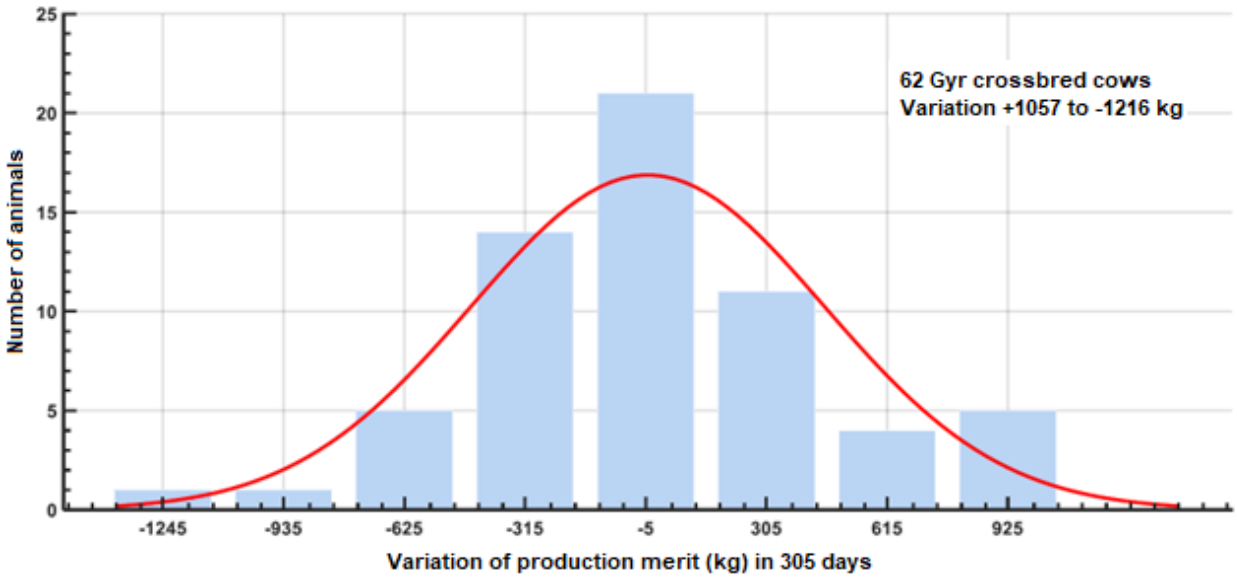

Figure 4. Variation in productive merit at 305 days of lactation

Accordingly, Pereira *et al*. (2012) reported genetic correlations close to zero between persistency and 305-day adjusted yield in Gyr cows, indicating that these traits can vary independently. The same author suggests that persistency should be calculated from the deviation in performance after day 30, since this measure showed heritability between 0.10 and 0.25. Similar results were obtained by Pereira *et al*. (2019) and Silva *et al*. (2023), who concluded that persistency should be analyzed as a trait in its own right rather than as a derivative of total yield.

CONCLUSIONS

Although preliminary, the repeatability coefficients ($r \approx 0.690–0.710$) indicate a consistent pattern of milk production in the Gyr × Holstein genetic groups, positioning them as a high-economic-interest alternative for producers in the province.

The observed range in total milk production (MP), with differences exceeding 2,000 kg over 305 days of lactation, demonstrates considerable productive variability among the animals. In addition, the estimated level of repeatability suggests that performance in the first lactation can be considered a good predictor of productive performance in subsequent lactations.

Finally, this study recommends expanding the database and performing a more in-depth analysis to estimate the genetic and environmental components involved, with the aim of generating more robust parameters for the selection and genetic improvement of herds under tropical conditions.

REFERENCES

Bastidas, R., Torres, A., Gómez, M., Seijas, C., Martínez, G., & Pérez, G. (2019). La producción de leche de un rebaño doble propósito. *Gaceta de Ciencias Veterinarias*, *24*(2), 2-9. https://revistas.uclave.org/index.php/gcv/article/view/3288

Balieiro, E. S., Pereira, J. C. C., Valente, J., Verneque, R. S., Balieiro, J. C. C., & Ferreira, W. J. (2000). Estimativas de parâmetros genéticos e de tendências fenotípica, genética e de ambiente de algumas características produtivas da raça Gir Leiteiro. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, *52*(3), 266-275. https://doi.org/10.1590/S0102-09352000000300017

Brito, L. F., Bedere, N., Douhard, F., Oliveira, H. R., Arnal, M., Peñagaricano, F., Schinckel, A. P., Baes, C. F., & Miglior, F. (2021). Review: Genetic selection of high-yielding dairy cattle toward sustainable farming systems in a rapidly changing world. *Animal*, *15*. https://doi.org/10.1016/j.animal.2021.100292

DeLaval. (2024). *DelPro Farm Manager*: *Software de gestión ganadera*. DeLaval International AB. https://www.delaval.com

Falconer, D., & Mackay, T. (1996). Introduction to quantitative genetics (4th ed.). Pearson Prentice Hall. https://ia803204.us.archive.org/2/items/introductiontoq00falc/introductiontoq00falc.pdf

Gilmour, A.R. (2021). Echidna Mixed Model Software. http://www.echidnamms.org

Guerra Montenegro, R., Menéndez-Buxadera, A., & Hernández-Rodríguez, A. (2019). Influencia de factores ambientales en la producción de leche de dos rebaños Holstein en la cuenca lechera de Chiriquí. *Revista Investigaciones Agropecuarias*, *2*(1), 18-33. https://revistas.up.ac.pa/index.php/investigaciones_agropecuarias/article/view/1063

Guerra, R., & Menéndez-Buxadera, A. (2020). Análisis comparativo de la repetibilidad para producción de leche en ganado Holstein puro o cruzado con Brown Swiss y Jersey en la cuenca lechera de Chiriquí. *Revista Investigaciones Agropecuarias*, *3*(1). http://portal.amelica.org/ameli/jatsRepo/222/2221956002/index.html

Napolis, C., Rodrigues de Melo, C., Crivelari, C., Ferreira de Freitas, A., Packer, I., & de Araújo Cobuci, J. (2005). Parâmetros genéticos para a produção de leite de controles individuais de vacas da raça Gir estimados com modelos de repetibilidade e regressão aleatória. *Revista Brasileira de Zootecnia*, *34*(5), 1519-1530. https://doi.org/10.1590/S1516-35982005000500012

Ortiz, G., Stephen F., Parés, I., Curbelo, J., Jiménez, E., Pagán, M., & Gould, W. (2018). Assessing climate vulnerabilities and adaptive strategies for resilient beef and dairy operations in the tropics. *Climatic Change*, *146*(1-2), 47-58. https://doi.org/10.1007/s10584-017-2110-1

Pereira, M., Faro, L., Savegnago, R., Costa, E., Filho, A., & Faria, C. (2021). Estimates of genetic parameters and cluster analysis of the lactation curve of dairy Gyr cattle. *Livestock Science, 244*. https://doi.org/10.1016/j.livsci.2020.104337

Pereira, R., Rocha, D., Santana, M., El Faro, L., Vercesi, A., & Galvão, L. (2019). Test-day or 305-day milk yield for genetic evaluation of Gir cattle. *Pesquisa Agropecuaria Brasileira, 54*. https://doi.org/10.1590/S1678-3921.pab2019.v54.00325

Pereira, R., Verneque, R., Lopes, P., Santana, L., Lagrotta, M., Torres, R., Vercesi Filho, A., & Machado, M. (2012). Milk yield persistency in Brazilian Gyr cattle based on a random regression model. *Genetics and Molecular Research, 11*(2), 1599-1609. https://doi.org/10.4238/2012.June.15.9

Silva, N., Dos Santos, D., Demesntshuk, J., Araújo, J., & Veiga, E. (2023). Genetic parameters and genetic trends for production traits in dairy Gir cattle. *Ciência Rural, 53*(11). https://doi.org/10.1590/0103-8478cr20210541

Vargas-Leitón, B., Romero-Zúñiga, J., Rojas, J., Galina, C., & Martínez, J. (2024). Lifetime milk production of Holstein cattle in the humid tropics compared to Holstein-Gyr and Holstein-Brahman crosses. *Reproduction in Domestic Animals, 59*(5). https://doi.org/10.1111/rda.14582

Vinet, A., Mattalia, S., Vallée, R., Bertrand, C., Barbat, A., Promp, J., Cuyabano, B., & Boichard, D. (2024). Effect of temperature-humidity index on the evolution of trade-offs between fertility and production in dairy cattle. *Genetics Selection Evolution, 56*(1). https://doi.org/10.1186/s12711-024-00889-4

AUTHOR CONTRIBUTION STATEMENT

Research conception and design: KAMV, RGGM; data analysis and interpretation: KAMV, AS, AMB; writing of the manuscript: KAMV, AMB, RGGM.

CONFLICT OF INTEREST STATEMENT

The authors state there are no conflicts of interest whatsoever.