Preliminary investigations into genetic variation in distance travelled by young sheep

Johnson PL*[1], N Cullen[2], SM Hickey[2], K Knowler[1], B Bryson[3], M Hall[3] and P Pletnykov[4]

[1]*Invermay Agricultural Centre, AgResearch Ltd., Private Bag 50034, Mosgiel, New Zealand;* [2]*Ruakura Research Centre, AgResearch Ltd., Private Bag 3115, Hamilton, New Zealand;* [3]*Woodlands Research Station, AgResearch Ltd., Woodlands RD1, New Zealand;* [4] *Lincoln Research Centre, AgResearch Ltd., Christchurch, New Zealand*

**Corresponding author:* Email: tricia.johnson@agresearch.co.nz

Abstract

In pastoral grazing systems, animals need to walk to obtain nutrients (pasture) and water, however, it is also thought that the distance an animal travels is further influenced by factors including the grazing behaviour of the animal, its health status and its general motivation for moving. The purpose of this research was to investigate the repeatability and genetic variation in the trait of distance travelled for New Zealand sheep. Data were collected using global positioning satellite (GPS) collars fitted to 422 animals from three different groups of animals (Group). The animals were allowed *ad libitum* grazing. Progeny from 44 sires were represented in the data set. The GPS collars were fitted for up to 17 days. Given between-day variability in distance travelled depending on paddock attributes (size and feed availability) all data were scaled to a constant mean. A univariate repeated measures model was fitted to the data using ASREML, with Group fitted within the model, and day within Group fitted as the repeated measure. The heritability estimate for daily distance travelled was 0.36±0.09, with a repeatability estimate of 0.51±0.03. The results indicate that distance travelled is a repeatable trait at the individual animal level and is under moderate genetic control.

Keywords: sheep; GPS; distance travelled

Introduction

In pastoral grazing systems, animals need to walk to obtain nutrients (pasture) and water (Coop & Drew 1961). The distance that they travel daily will be influenced by their energy requirements, the type and availability of feed within the area that they are grazing, and their physiological status (Nicol & Brookes 2007). However, other factors are likely to also contribute to the distance that an animal walks daily including social structure (hierarchy), the grazing behaviour of the animal, its health status and general motivation for movement. Walking is an energy expense and equations that predict energy requirements for animals can include specific equations for distance travelled (Nicol & Brookes 2007).

The majority of data sets that consider distance travelled by sheep have been relatively small data sets in the context of the use of landscape features, e.g., Bunyaga et al. (2020) or variability as it relates to climatic variation, e.g., Thomas et al. (2008), and have not considered distance travelled as a trait, and its potential repeatability or genetic origin. There is evidence, however, as reviewed by van Oers and Sinn (2013), that genetic variation exists as to how animals behave and interact with their environment. The purpose of this study was to provide first estimates for the heritability of distance travelled for New Zealand sheep in a pastoral grazing system.

Materials and methods

Trial location and animal type were chosen to ensure that the animals could all be viewed twice daily given that these were newly designed collars, to eliminate risks associated with the animals becoming entangled in fences or other objects. As such, the best resource for this first-stage research was a flat-land property with easy visual inspection of all fences within the paddocks. All data collection was approved by the AgResearch Animal Ethics Committee.

Collars and GPS Data

The collars used were custom-made (manufacturer DataCarter) for use in sheep, with GPS componentry and an 18Ah D cell lithium thionyl battery within 3D printed housing made of thick plastic, with a webbing collar and a plastic clasp used to secure the collar around the neck. The weight of the housing and battery (approximately 290 g) was sufficient for the housing to be held on the underside of the neck of the animal with minimal shifting. The GPS componentry was based on a passive antenna and a UBlox NeoM8 chip. The chips were programmed to record a position when the animal moved more than five meters, or if stationary, a position was recorded at ten-minute intervals. The position was recorded as latitude and longitude coordinates, which were loaded into ArcGIS 9 (ArcMap Version 9.3, USA) for further processing and analysis. The batteries were estimated to last for 18 days, with a draw of 1Ah per day. Data was stored on an onboard SD card, and were downloaded after the final set of data was collected within a contemporary group.

Animals

Data were collected from three contemporary groups of animals within research flocks run at AgResearch Woodlands, Invercargill, New Zealand between October 2018 and March 2020. For all animals, sire and dam information was available, confirmed through DNA parentage testing.

The first data set was based on 2017-born ewes from the AgResearch Progeny Test Research maternal flock (Brito et al. 2017), with data collected on the animals when they were approximately 14 months of age in October 2018. GPS collars were fitted on 300 animals which were randomly allocated to one of three groups (Group 1-3) as only 100 collars were available at any one time. The GPS collars were fitted on a group of animals for one week and then rotated to the next group of ewes. After the collars had been fitted on the third group, collar deployment was repeated starting with the first group. Ultimately each animal had up to two periods of data available (Period 1 and 2) but issues with the collars, GPS componentry and batteries meant only 111 animals had data for both periods. A further 154 animals had data for a single period.

The second data set was based on 2018-born ewe lambs from the AgResearch methane-selection lines (Pinares-Patiño et al. 2013), with data collected on the animals when they were approximately nine months of age in June 2019. The GPS collars were fitted on 100 animals for 17 days, resulting in 74 animals with a full set of data available.

The third data set was based on 2019-born ram lambs from the AgResearch methane-selection lines (Pinares-Patiño et al. 2013), with data collected on the animals when they were approximately five months of age in March February 2020. The GPS collars were fitted on 100 animals for 17 days, resulting in 83 animals with a full set of data available.

Management

All animals were run at AgResearch Woodlands, which is in inland Southland (-45.969738 S, 168.745323 E) and is 34 metres above sea level. The property is nearly exclusively flat and is subdivided into paddocks ranging from less than 0.5 hectares to 3.5 hectares in size. It is in an area of moderate-to-high rainfall year-round (Smith 2012). For these studies, the animals were provided access to several paddocks at one time to allow *ad-libitum* intake for the duration of data collection. The paddocks consisted of ryegrass/white clover swards of high quality (Smith 2012).

Analysis

Data sets were edited to remove records that occurred during the time of turning on and fitting of the collars, together with the movement of animals between the yards and the paddocks and *vice versa*. Data during the grazing period were also processed to remove data points that did not map within the paddock boundaries, however, less than 1% of data points needed to be removed for that reason.

The cleaned GPS data sets were analysed using ArcGIS to determine the distance travelled (sum of individual records) within a 24-hour period starting at midnight the day the collars were fitted and ending at midnight the night before the collars were removed. Although all animals were given *ad libitum* access to feed, there was variability in paddock sizes and differences in offered pasture quality and quantity among groups of animals, even for the same animals during days and weeks. To account for this, the data were expressed as a proportion of their contemporary group (CG) mean multiplied by the global mean for that Group of animals as described by Brito et al. (2017). Data for the 2017-born animals were collected across two time periods, approximately three weeks apart, and for this group of animals CG corresponded to group and week; for the two other groups of animals, all data were collected across a consecutive time period. Variance and covariance components were estimated using restricted maximum likelihood (REML) procedures fitting an animal model in ASReml (Gilmour et al. 2015). The file was structured such that each animal had multiple data points corresponding to the different days for which the collars were fitted. A single repeatability and heritability estimate was generated by fitting day as a repeated measure. Group was fitted as a fixed effect, given the data had been scaled by contemporary group, no additional variables were fitted in the models. Pedigree data for use in the analysis were obtained from Sheep Improvement Limited (Newman 2009).

Results and discussion

As indicated in the materials and methods, not all GPS collars successfully generated data, however, where data sets were generated they were considered to be sound based on producing expected locations and complete data sets for at least 12 days. The average distance travelled (DT) across all data sources was 3.4±0.89 km/day. Phenotypically, there was a large range in coefficients of variation (CV) among days for individual animals, ranging from 4-8% (consistent) to 28-60% (inconsistent) in the different data sets. The largest amount of variation was observed in the first data set where data were collected in two different periods three weeks apart. In all cases, data were not available for all animals on which the collars were fitted. There were several reasons for this loss of data, with a combination of battery connection issues and GPS chip malfunctions reducing the size of the final data set, highlighting that development work is still required to optimise the design of the GPS collars.

For the first data set, there were examples of animals that exhibited consistency in distance travelled between time periods, but some animals were not consistent. Examples of such animals are in Fig. 1, including an example of an animal that consistently travelled low or high distances between the two weeks of measurement respectively, and an animal that was not consistent between the two weeks. A visual representation of examples of animals exhibiting extremes (high and low) for distance travelled per day is in Fig. 2. The animal that was extreme for not travelling long distances averaged 1958 m per day (range 1427 to 2205 m per day), whilst the animal that was extreme for travelling long distances averaged 4534 m per day (range 3366 to 5332 m per day).

Data from the first data set is given in Fig. 3 which compares the average distance travelled for each group for the two measurement periods. Overall, for each of the three groups, there was a good phenotypic correlation between the two data sets for each animal (R^2 range 0.54-0.67). For the data sets collected in subsequent years, there was similar variability between extreme animals, as shown in Fig. 4.

Figure 1 Examples of the distribution of distances travelled per day from the first data set for an animal consistently travelling a low distance per day (left) across the two measurements weeks (W1 or W2), a high distance per day across the two measurement weeks (middle) and one individual that changed the distance travelled per day significantly between the two measurement weeks (right). Each plot represents 12-17 days worth of data.

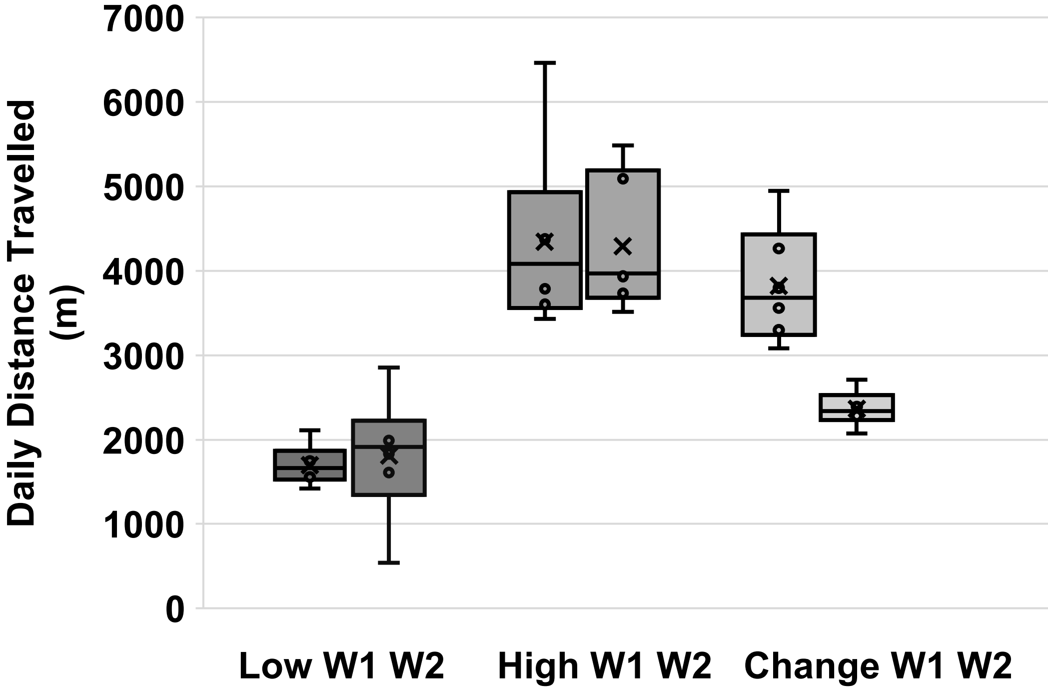
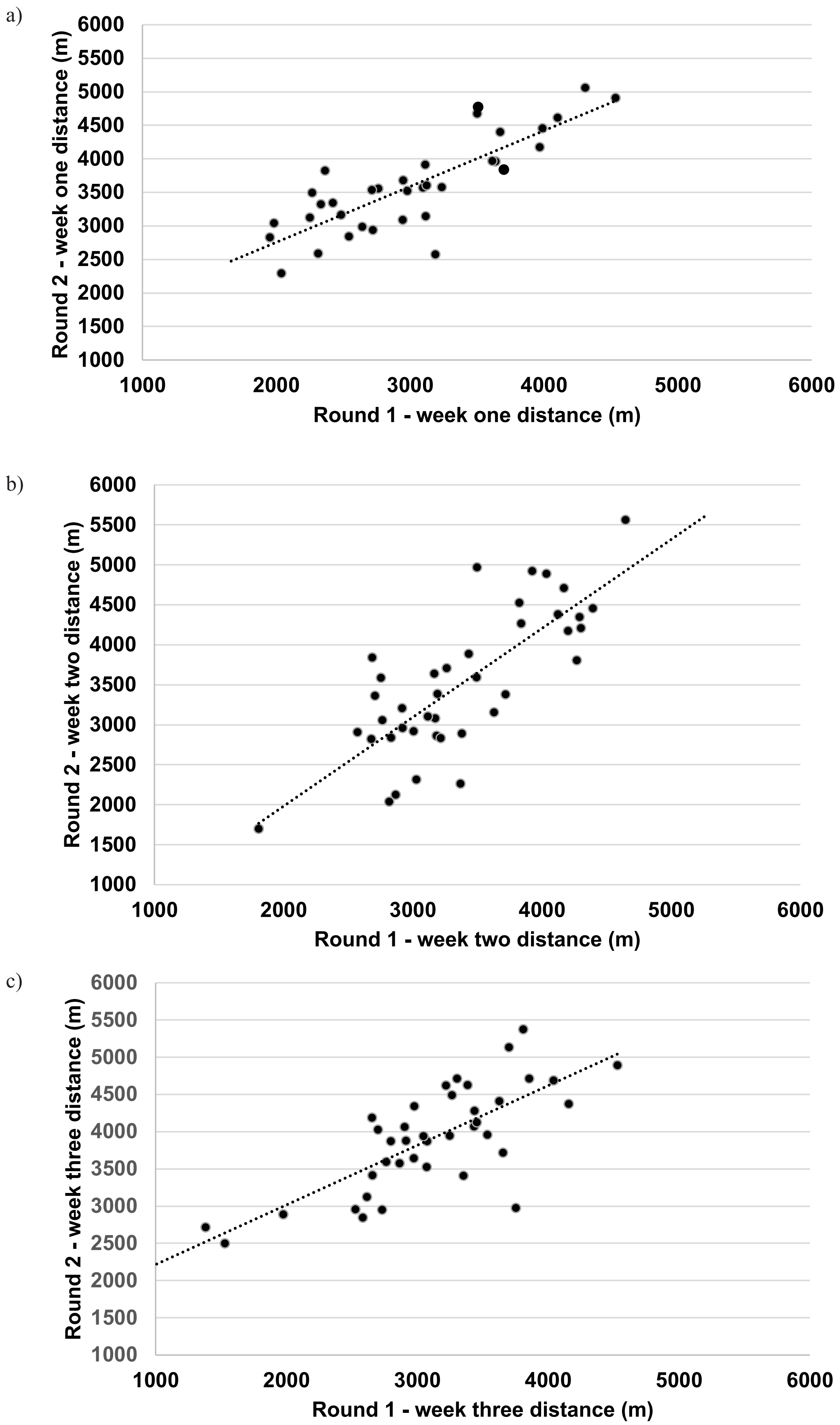


Figure 2 Example of GPS traces for two sheep exhibiting extremes in distance travelled. The animal with the dark-coloured trace travelled on average 1958 m per day (range 1427 to 2205 m per day) whilst in these paddocks, whilst the animal with the light-coloured trace travelled on average 4534 m per day (range 3366 to 5332 m per day).

Figure 3 Raw phenotypic correlations between distances travelled between the first and second periods of measurement (seven-day measurement periods separated by three weeks) for three groups of animals. a) 1st group of animals, R^2=0.67; b) 2nd group of animals, R^2=0.61; c) 3rd group of animals, R^2=0.54.



Whilst some technical issues limited the size of the data set (compared to that originally targeted), the amount of data was still sufficient to estimate the heritability and repeatability when all data were considered as a repeated measure in the same analysis. The heritability estimate for daily distance travelled was 0.36±0.09, with a repeatability estimate of 0.51±0.03. The design of studies was targeting the estimation of the repeatability of distance travelled, which means that the heritability estimate benefited from multiple measures on each individual within the data set. The results demonstrate that the trait of distance travelled is under genetic control and is a repeatable (across days within a period of weeks) attribute of an individual.

Whilst several papers describe the distances covered by sheep in different environments (Thomas et al. 2008; Bunyaga et al. 2020), this is the largest data set to date. This has allowed the determination of the repeatability of the trait of distance travelled, and the ability to generate a preliminary heritability estimate. No comparable data sets have been found for any production animal species. A review by Fogarty et al. (2018) reported that most GPS data sets in production animals are based on low numbers of animals without pedigree records. Increased reliability of GPS chips and batteries would have increased the size of the data set. Despite this, the data were adequate to provide accurate repeatability and heritability estimates. There are, however, factors that appear to affect the repeatability of the distance travelled by individual animals, with some animals exhibiting significantly different walking distance behaviours between the two time periods. It is known that disease conditions such as parasites or other sub-clinical issues will impact on distances that animals walk, and this is used as a method for identifying sub-clinically sick animals using technologies such as pedometers.

Given that distance travelled has an energy cost associated with it, the large (over two-fold variation) in distances covered by different animals highlights the need to incorporate such trait data when considering traits such as residual feed intake, where the most common models only account for live weight and liveweight gain. The trait of residual feed intake is the error term in a model and, therefore, traits like distance travelled could account for some of this error.

Conclusion

This data set is the most comprehensive data set to date to consider the distance travelled by individual sheep in a pastoral grazing system. The results demonstrate that distance travelled is a repeatable trait at the individual animal level, but that it can be influenced by factors thought to include parasite burden or other sub-clinical illnesses. The results also demonstrate that it is a moderately heritable trait. Genetic variation in walking distance will influence energy partitioning and potential intake. The potential for GPS data to reveal further information about grazing behaviour and how animals interact with their environment will be the next stage of analysis on the existing data set.

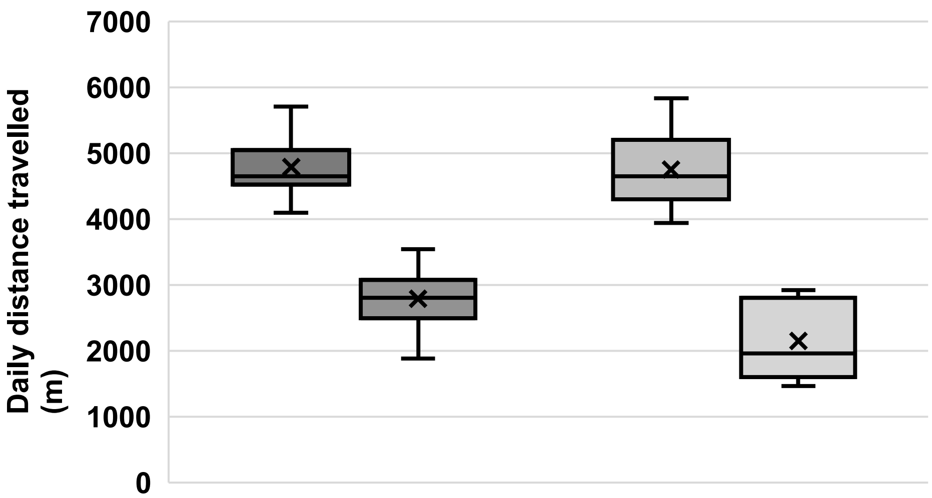
Acknowledgements

Funding for this series of studies was sourced from AgResearch Strategic Science Initiative Funding.

References

Brito LF, McEwan JC, Miller SP, Bain WE, Lee M, Dodds KG, Newman S-A, Pickering NK, Schenkel FS, Clarke, SC 2017. Genetic parameters for various growth, carcass and meat quality traits in a New Zealand sheep population. Small Ruminant Research 154: 81-91.

Figure 4 Examples of the distribution of distances travelled per day over ten to seventeen days from two different sets for animals consistently travelling a high distance per day (left within data set), or a low distance per day (right within data set). Data set two animals were ewe lambs from the AgResearch methane selection lines, with data collected on the animals when they were approximately nine months of age. Data set three animals were ram lambs from the AgResearch methane selection lines, with data collected on the animals when they were approximately five months of age.



Bunyaga AS, Corner-Thomas RA, Burkitt LL, Draganova I, Kenyon PR 2020. BRIEF COMMUNICATION: The behaviour of sheep around a natural waterway. New Zealand Journal of Animal Science and Production 80: 124-127.

Coop IE, Drew KR 1961. Maintenance and lactation requirements of grazing sheep. Proceedings of the New Zealand Society of Animal Production 21: 53-62.

Fogarty ES, Swain DL, Cronin G, Trotter M 2018. Autonomous on-animal sensors in sheep research: A systematic review. Computers and Electronics in Agriculture 150: 245-256.

Gilmour AR, Gogel BJ, Cullis BR, Thompson R 2015. ASReml User Guide Release 4.1. VSN International Ltd, Hemel Hempstead, Hertfordshire, UK.

Newman S-AN 2009. Sheep Improvement Limited (SIL) – the first 10 years. Introductory remarks. Proceedings of the New Zealand Society of Animal Production 69: 148.

Nicol AM, Brookes IM 2007. The metabolisable energy requirements of grazing livestock. In: Rattray PV, Nicol, AM, Brookes, IM eds Pasture and supplements for grazing dairy cattle New Zealand Society of Animal Production, Hamilton New Zealand Occasional Publication 14. pp 151-172.

Pinares-Patiño CS, Hickey SM, Young EA, Dodds KG, MacLean S, Molano G, Sandoval E, Kjestrup H, Harland R, Hunt C, Pickering NK, McEwan JC 2013. Heritability estimates of methane emissions from sheep. Animal 7: 316-321.

Smith LC 2012. Long term pasture growth patterns for Southland New Zealand: 1978 to 2012. Proceedings of the New Zealand Grassland Association 74: 147-152.

Thomas DT, Wilmot MG, Alchin M, Masters DG 2008. Preliminary indications that Merino sheep graze different areas on cooler days in the Southern Rangelands of Western Australia. Animal Production Science 48: 889-892.

van Oers K, Sinn DL 2013. Quantitative and molecular genetics of animal personality. In: Carere C, Maestripieri D, eds. Animal Personalities: Behavior, Physiology, and Evolution. Chicago, IL: The University of Chicago Press pp 149-200.