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Kinematic parameters of sheep walking on a treadmill

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Abstract

Ovine locomotion studies are rare, despite their relevance for medical research. The aim of this preliminary study was to investigate habituation and temporospatial parameters during treadmill walking of seven Austrian Mountain sheep. Sheep were naïve to treadmill exercise. During five treadmill sessions, movement cycle duration (MCD), vertical trunk movement (VTM), stride height (SH), stride length (SL), and percentage of movement cycle at stance (%St) were assessed. Two sheep were excluded from the study because they would not walk on the treadmill. From the end measurement session, MCD (0.95 s) and %St (62%) were similar to reported kinetics of sheep walking over ground, although stride length (1.05 m) was longer in this study. These findings suggest that sheep may require more than five sessions to become habituated to treadmill walking.

Keywords

Sheep; Locomotion; Kinematics; Habituation; Treadmill

Live sheep are commonly used as an animal model for orthopaedic research. Due to the similarities between ovine and human skeletons, sheep are often used in studies of the human spine (Reitmaier et al., 2013) and knee joints (Tapper et al., 2006, 2008). Extrapolation from sheep models to humans can only be meaningful if biomechanical interspecies variations are well documented. As a part of a larger comparative biomechanical human and sheep study, this study examined some key aspects of ovine locomotion. While the kinetics of sheep locomotion over ground have been reported (Kim and Breur, 2008; Agostinho et al., 2012), adequate descriptions of temporospatial locomotion parameters in healthy sheep using a kinematic set-up and treadmill are lacking, as are the number of training sessions required for treadmill habituation. Therefore, the aim of this study was to report kinematic parameters in mature sheep during treadmill walking, and to identify habituation to treadmill walk over five treadmill sessions.

Seven mature Austrian Mountain sheep (2.1 ± 0.88 years; 72.2 ± 7.29 kg) were included. All sheep were accustomed to walking and trotting in-hand over the non-moving treadmill (Mustang 2200, Kagra). Ethical approval was granted from the Austrian Federal Ministry of Science and Research (13/10/97/2011).

All of the sheep were deemed to be sound by an experienced orthopaedic veterinarian. Reflective markers were attached to the head, withers, sacrum, and below each fetlock joint. Ten high speed cameras (Eagle Digital Real Time System; 1200 Hz) were used for kinematic data collection using kinematic software (Cortex 3.6, Motion Analysis). Data were collected during four treadmill training sessions (A–D) and an end session (E), against which all measurements were compared. Training days were interspersed by over ground exercise only or rest (Table 1). Sessions A–D consisted of three measurement intervals at walk; at baseline (immediately as individual comfortable speed was reached – 0 m), 1 min (1 m) and 2 min (2 m). At each measurement interval, data were collected for three 10 s intervals.

Movement cycle duration (MCD), mean vertical trunk movement measured at the withers (VTM), stride height (SH), stride length (SL), and percentage of movement cycle at stance (%St) for each limb were determined using scripts written in MATLAB (Mathworks) and Excel (Microsoft). Variability of parameters was defined as the mean value for each sheep at each measurement (A–D; 0–2 m) subtracted from the mean value E. Consistency of locomotion was determined by the standard deviation of each measurement (A–E; 0–2 m).

Parametric tests were used for normally distributed data and non-parametric statistical tests were used for data that were not normally distributed. ANOVA or Friedman's ANOVA was used for within-session comparisons (0–2 m), and paired *t* tests or Wilcoxon rank tests for between-session comparisons (A–D; 0–2 m with the end session E). A Bonferroni correction was used with ANOVA and pairwise comparisons with Friedman's ANOVA as post-hoc comparisons using SPSS version 19 (IBM). For this study, habituation was reached as soon as no significant differences in variability and consistency were found compared to the end session (E).

Two sheep were excluded from the study as they refused to walk on the treadmill, even when tempted with feed. Data from the remaining five sheep, which all completed each measurement interval, are reported. Outcomes of E are displayed using averaged data for the fore- and hindlimbs for comparison with existing studies (Table 2). Individualised speed ranged from 1.11 to 1.16 m/s. Only A MCD variability showed a significant within-session difference (0 m and 2 m; $P = 0.034$). For variability, significant differences from E occurred throughout A–D for SH (all limbs; 21/48 comparisons; $P < 0.05$), A 2 m left forelimb for SL ($P = 0.038$) and A 0–2 m left hindlimb for %St ($P < 0.05$). For consistency, significant differences from E occurred throughout A–D for MCD (6/12 comparisons; $P < 0.05$), A 0 m and A 2 m for VTM ($P < 0.05$), A–C for SH (all limbs; 12/36 comparisons; $P < 0.05$), A–D for SL (all limbs; 13/48 comparisons; $P < 0.05$), and A–D for %St (hindlimbs; 4/24 comparisons; $P < 0.05$). Fig. 1 shows the standard deviations reported as a percentage of the mean of all parameters investigated in all sheep combined for each measurement.

Healthy and mature humans with limited prior treadmill experience have been found to habituate to treadmill walking within 10 min of their first measurement session (Van de Putte et al., 2006). However, the findings from this study showed that even after four training sessions, Austrian Mountain sheep did not habituate to treadmill walking. Similarly, horses have also shown non-habituation to treadmill walking after nine training sessions over 5 days (Buchner et al., 1994). No other studies have been identified which investigated the habitation of animals to walk on a treadmill.

The over ground walking cycle duration reported by Kim and Breur (2008) in Suffolk sheep is similar to the MCD in this study. Furthermore during over ground walking, stance durations of Suffolk sheep (Kim and Breur, 2008) and Santa Ines sheep (Agostinho et al., 2012) ranged from 59.09% (± 0.73) to 66.31% (± 3.41) in the forelimb and 61.32% (± 1.71) to 68.89% (± 4.03) in the hindlimb, which was also similar to this study. However, these studies reported shorter stride lengths (0.84 ± 0.05 m to 0.85 ± 0.07 m) in comparison to this study, which may be due to differences in breed investigated and measurement approach (kinematic vs. kinetic; treadmill vs. over ground). Further, standard deviation as a percentage of mean stride length in this study (4.7%) was slightly lower than that found in the kinetic studies (6–8.2%), indicating that consistency of walk was similar to over ground locomotion.

In conclusion, mature Austrian Mountain sheep cannot be considered habituated to treadmill walking over five sessions, although consistency did improve with time and was similar to over ground locomotion. To our knowledge, this is the first study to describe treadmill walking kinematic outcomes in mature sheep. Future studies should explore similar parameters for trot, the required training time to achieve habituation, and the best training approach to habituate sheep to treadmill locomotion. This information is intended to serve as a baseline against which animal studies using sheep could compare their findings. It also highlights the contrasts between over ground and treadmill locomotion of sheep.

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Fig. 1. Standard deviations (depicted as a percentage of the mean) of all parameters (movement cycle duration, vertical trunk movement measured at the withers, stride height, stride length, and percentage of movement cycle at stance for each limb) for all sheep from each session (A–E) and measurement interval (0–2 m).

Table 1

Training programme (A–E, training session A–E; OE, overground exercise; R, rest).

Day	1	2	3	4	5	6	7	8	9	10
Activity	A	OE	B	OE	C	R	R	D	OE	E

Table 2

Mean, standard deviation (S.D.) and median of end session (E) outcomes for movement cycle duration (MCD), vertical trunk movement (VTM), stride height (SH), stride length (SL) and percentage of stride as stance (%St) for the forelimbs (FL) and hindlimbs (HL) for five Austrian Mountain sheep.

	MCD (s)	VTM (mm)	SH (mm)		SL (mm)		%St	
			FL	HL	FL	HL	FL	HL
Mean	0.95	800.74	48.49	54.93	1053.12	1051.41	61.48	62.90
S.D.	0.08	45.24	12.68	10.58	49.28	49.08	4.35	4.08
Median	0.92	798.46	49.42	54.29	1071.80	1066.68	60.74	62.24