Reducing the energy cost of dragging sheep during sheep shearing

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The task of dragging sheep into position for shearing has been reported by shearers as the most physically demanding and one of the highest injury risk aspects of shearing, particularly with regard to back injury. This study aimed to identify which of the currently used drag paths induced the lowest energy consumption and risk of injury. The drag path with the lowest work economy (oxygen cost per sheep dragged per minute) and highest injury risk is used by left-handed shearers who are shearing from a workstation which is designed for right-handed shearers. Importantly, there were no significant differences in the work economy of the two drag paths which were used most frequently and which involved the lowest injury risk. These data have been used in advocating the adoption of simple shearing shed design solutions to assist in the control of injury risk and energy expenditure in the wool industry.

KEYWORDS

- SHEEP SHEARING
- ENERGY EXPENDITURE
- BACK INJURIES
- SHEEP DRAG PATHS

Introduction

Sheep shearing has remained relatively unchanged during a century which has seen the majority of heavy manual handling occupations either replaced by varying forms of automation or assisted by mechanical aids. The sheep shearer is required to catch, tip and drag the sheep into a position for removal of the fleece from the sheep, shear off the fleece and finally guide the sheep to the point of release. This task can be completed in excess of 200 times a day. Extensive task analysis and workplace auditing have indicated that there are a number of standard drag paths used within the industry.[1]

In an earlier study, it was reported that shearers believe that the drag is one of the most physically taxing components of shearing.[1] It can be estimated that a shearer will drag in excess of 14 tonnes of sheep (approximately 200 sheep at approximately 70 kg each) over an eight-hour workday. Additionally, shearers believe that a drag path which requires considerable rotation and sheep manoeuvring is a risk factor associated with the high rate of back injury reported within the industry.[1,2] This study was undertaken to determine the most economic and lowest injury risk of the commonly used sheep drag paths.

Methods

Subjects

Seven professional sheep shearers volunteered to participate in the study. Five were full-time shearers (that is, worked as a shearer for more than six months per year), and the remaining two were part-time shearers (that is, worked as a shearer for less than six months per year). Each shearer was capable of shearing over 200 mature sheep per day. The work status and physical and anthropometric characteristics of each subject are outlined in Table 1. Each subject was cleared to participate in the study following a musculoskeletal evaluation. The Human Research Ethics Committee of the University of Ballarat approved the study, and each subject gave written informed consent to participate in the study.

Procedures

Physical and anthropometric characteristics of the subjects were determined prior to participation in the energy expenditure trials. Height was measured using a staidiometer and weight was measured using an Avery electronic scale (± 20 gm). Body mass index was determined using the method outlined by Norton et al.[3] Maximal oxygen consumption was estimated by measuring the heart rate response to a submaximal graded exercise test on a Monark (Model 810) cycle ergometer.[4]

TABLE 1

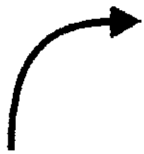
Subject work status and physical and anthropometric characteristics

Shearer	Part/full time	Age (yrs)	Height (cm)	Body weight (kg)	Body mass index ($kg.m^{-2}$)	$VO2_{max}$ ($mL.kg.^{-1}.min^{-1}$)
1	PT	44	170.0	64	22.2	31.4
2	PT	41	186.0	141	40.8	26.2
3	FT	40	178.0	72	22.72	48.6
4	FT	34	180.0	99	30.5	55.6
5	FT	32	188.5	87	24.5	56.3
6	FT	20	188.5	76	21.4	56.7
7	FT	26	170.7	56	19.2	53.4

Five commonly used drag paths identified from workplace audits were used during the study (Table 2). Normally, the dragging subtask takes less than 10 seconds to complete. However, in order to examine the energy cost of the activity, it was necessary to design the dragging subtask in such a way to achieve a steady rate of energy expenditure. Therefore, each shearer was required to drag sheep continuously over a given drag path for a total of three minutes. Each drag trial involved the shearer repeatedly dragging a sheep over the designated drag path, handing the sheep to an assistant, walking back to the beginning of

TABLE 2

Description of drag paths

Path	*Shape*	*Coordinates* (x,y) (mm)*	*Approximate length (mm)*
A		(900, 1,350)	1,850
B		(0, 1,950)	2,450
C		(-800, 1,500)	2,500
D		(-750, 950)	1,350
E		(1,000, 750)	3,100

* These coordinates refer to the position of the end of the drag path to the right or left (x) and out (y) from the centre of the catching pen door. These positions were approximately 450 mm from the downtube/handpiece positions.

TABLE 3

Mean (± SE) oxygen uptake (L.min⁻¹ and % max) for each shearer during sheep dragging

	Shearer						
	1	*2*	*3*	*4*	*5*	*6*	*7*
$L.min^{-1}$	2.46	2.28	2.03	3.39	2.34	2.49	1.94
% max	(123%*)	(61.6%)	(58%)	(61.6%)	(47.8%)	(57.9%)	(62.6%)
SE	0.09	0.09	0.09	0.09	0.09	0.09	0.09

* It is likely that the aerobic capacity for subject 1 was underestimated.

the drag path and taking control of another sheep that was positioned ready to be dragged over the designated path. In this way, the subtask of dragging was separated from the subtask of tipping. A total of three sheep (weight range: 69.5–73.2 kg) were used during the drag task. At the end of each drag, the shearer indicated the completion of the task by touching a shearing handpiece which was on the floor. Each shearer attempted to replicate the normal pace of dragging used when working. The number of drags completed during each three-minute trial was recorded. The drag patterns were performed in random order. The assessment period for each subject consisted of seven (five drag patterns plus replications of two patterns) three-minute work periods. Each work period was separated by a five-minute recovery period which was undertaken in a seated position. Energy consumption was measured over the entire assessment period using either AeroSport (n = 2) or Cosmed K4 (n = 5) portable metabolic testing systems. The metabolic testing systems were calibrated according to the respective manufacturer's instructions prior to use by each subject. The steady rate oxygen uptake was adopted as the oxygen uptake for the final (third) minute of each dragging period.

Design and data analysis

The two-factor (shearer × path of drag) design was partially replicated. Each shearer repeated two randomly assigned paths; three of the five paths were repeated by three shearers and two by two shearers. Full replication was not possible because of practical constraints of participant and laboratory availability. The partially replicated design was a compromise which enabled an assessment of any shearer–path interactive effects. Oxygen uptake ($L.min^{-1}$) and oxygen uptake per sheep dragged were each analysed in a two-way analysis of variance (ANOVA) using the Statistical Package for the Social Sciences.[5] Because of the unbalanced layout, with not all shearers using all paths the same number of times, the means for paths were adjusted for differences between shearers and vice versa. Standard errors (SE) were derived from the residual mean square from the analysis of variance. Post-hoc comparisons were performed using Newman-Keuls analysis. All statistical tests were undertaken at $p < 0.05$ level of significance.

Results

The mean (± SE) oxygen uptake ($L.min^{-1}$) for each shearer and for each drag path are shown in Tables 3 and 4. There was a significant difference in the rate that oxygen was consumed by the individual shearers ($p < 0.0005$); however, there was no significant difference in the rate of oxygen consumption between the respective drag paths ($p = 0.16$). There was also no interaction between the rate of oxygen consumption for shearer and path of drag ($p = 0.579$).

The mean rate (± SE) of sheep dragging ranged from 5.0 ± 0.9 to 6.0 ± 0.8 sheep per minute over the five drag paths. In order to explore the impact of the apparent variability in work rate, the energy expended was normalised to account for the number of sheep

TABLE 4

Mean (± SE) steady rate oxygen uptake ($L.min^{-1}$) for each drag path

	Drag path				
	A	B	C	D	E
Mean	2.33	2.39	2.40	2.39	2.58
SE	0.07	0.07	0.07	0.07	0.07

dragged within each trial period. The calculated data for oxygen uptake per sheep by path of drag and shearer are presented in Figure 1 and Table 5, respectively. These data indicated that there were significant differences between the energy expended per sheep dragged by each shearer ($p < 0.0005$) depending on the drag path taken ($p < 0.0005$). There was, however, no significant interaction between shearer and drag path ($p = 0.495$). Newman-Keuls post-hoc analysis indicated that there were a number of significant differences between the respective drag paths for the relative amount of oxygen consumed ($mL.sheep\ dragged^{-1}$) (Figure 1).

Discussion

When compared with other tasks, sheep shearing can be classified as a task that is "very heavy".[6] The extreme level of energy required by the sheep dragging subtask was confirmed by the average steady rate oxygen cost for the activity of 2.42 (± 0.03) $L.min^{-1}$. The level of energy expended during steady rate sheep dragging was 51% higher than the average oxygen cost for the overall work of shearing estimated by Stuart (1.60 $L.min^{-1}$).[7] Clearly, any reduction in the distance over which the sheep has to be dragged in order to position the sheep for shearing will be beneficial to the wellbeing of the shearer. The benefit may occur through a reduction in the amount of work being undertaken or through an increase in work efficiency by the shearer.

In addition to the physical nature of sheep shearing, injury data indicate that shearers incur a very high level of injuries (151.1 compensation claims per 1,000 shearers per year compared with the all-injury average of 26 compensation claims per 1,000 wage and salary earners per year).[2] Further, 19.6% of these injuries are sustained to the back and constitute 50% of the cost of shearing injuries.[2,8] Shearers have reported that the complexity of the dragging subtask (the number and extent of turns completed while dragging the sheep) is strongly related to the likelihood of incurring a back injury during shearing.[1] The influence of drag path complexity on the occurrence of back injury is likely to be due to the varying rotational nature of the paths, together with the fact that the dragging subtask follows a period of approximately three minutes where the shearer is required to adopt a posture of extreme lumbar flexion during fleece removal.[9]

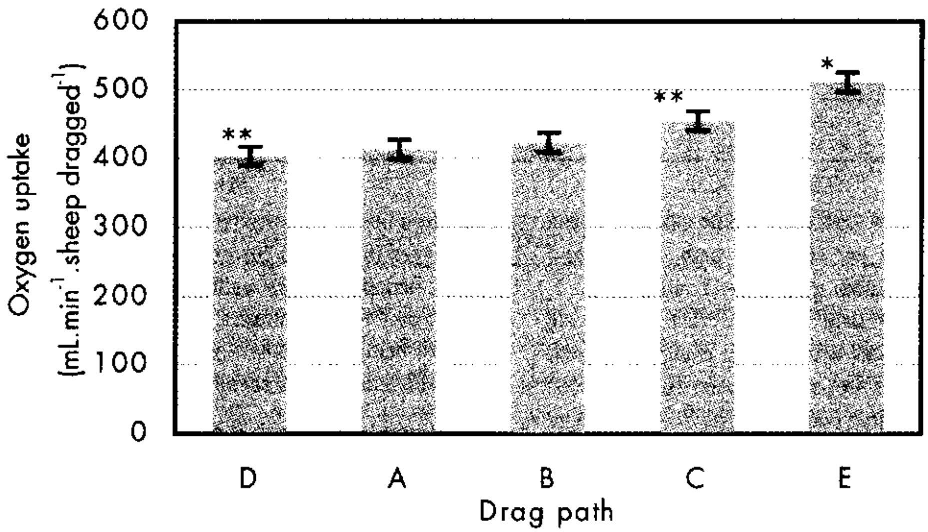
TABLE 5

Mean (± SE) oxygen uptake per sheep dragged ($mL.sheep\ dragged^{-1}$) for each shearer

	Shearer						
	1	2	3	4	5	6	7
Mean	394.0	531.6	388.7	541.0	445.4	449.3	335.0
SE	16.5	16.5	16.5	16.5	16.5	16.5	16.5

FIGURE 1

Mean oxygen uptake per sheep dragged (mL.min⁻¹) for each of the five drag paths outlined in Table 2 (data are mean ± SE)



* Drag path E is significantly greater than all other drag paths ($p < 0.05$).

** Drag path C is significantly greater than drag path D ($p < 0.05$).

The dragging patterns followed during this study were representative of the range of dragging paths normally encountered by a shearer. Irrespective of the length and complexity of the dragging task, the data obtained in the current study indicated that the shearers expended a similar level of energy in undertaking the various forms of work. The common level of energy expended indicated that the shearers were likely to be working to a self-regulated exertional limit. The notion that workers engaged in tasks which demand a high level of physical exertion self-regulate their level of exertion has been reported previously.[10] However, it should be noted that the steady rate of energy consumption observed in the current study was higher than the value of 40% reported previously by Astrand.[10] The higher rates of energy consumption are likely to reflect the intermittent nature of the subtask and/or the competitive nature of the shearing workplace. These data indicate that a better-designed work environment is unlikely to result in the shearer expending less energy; rather, the benefits are likely to accrue as increased work rate, decreased work complexity and decreased injury risk. It can also be observed that the measurement of oxygen consumption (absolute) was unable to be used to demonstrate the impact of differing levels of work task complexity.

The data were expressed as oxygen uptake per sheep dragged in an attempt to illustrate the likely benefit of the less complex drag paths on work economy. Work undertaken using one of the more acceptable drag paths (that is, drag path D, being the shortest distance and involving minimal (90°) rotation of the sheep) was the most economic. Importantly, given the low level of rotation required to perform drag path D, this path is likely to result in low levels of strain being placed on the back. Two of the drag patterns most often encountered by right-handed shearers are paths B and D. Drag path B is often found in shearing sheds built before 1950. It involves a long drag but little or no sheep rotation. Drag path D is often found in more recently constructed shearing sheds. The energy expenditure data obtained from the current study indicated that the reduction in average rate of energy expended when dragging sheep over path D when compared with path B (4.7%) was not statistically significant. Shearers using drag path D were 21.1% more efficient than when using the most complex drag path (path E). Drag path E (or its reflection) is often used by left-handed shearers who are forced to shear from a workstation which has been designed for a right-handed shearer, and is a good example of inappropriate workstation design.

Conclusion

The results of this study illustrate the extreme levels of energy required to drag a sheep into position for shearing. The data further demonstrate that the path of drag has a significant impact on the work economy of the shearer. In particular, the left-handed shearer, shearing from a workstation designed for a right-handed shearer, is at greatest disadvantage. It is recommended that shearing sheds be designed to enable the needs of left-handed shearers to be accommodated. It was also observed that the work efficiency of shearers using workstations in older shearing sheds is not significantly different from those encountered in newer sheds, despite the greater distance of the dragging subtask required in the older shearing sheds.

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