The interaction between skill, postures, forces and back pain in wool handling

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Abstract

Wool handling is an important rural occupation where workers process 200 or more fleeces daily, separating them into various quality components. Loads and postures they experience carry substantial risk of low back pain (LBP). Although a formal skill training structure exists, interaction with loads and LBP is unknown. We examined whether skill and LBP influenced trunk postures and loads of 60 wool handlers representing 3 skill levels. LBP prevalence ranged from 20% for junior (lowest skill) to 45% for open class (highest skill) wool handlers. Open class wool handlers demonstrated increased lateral bend and more axially twisted postures, generating greater medio-lateral shear forces and lateral bend and axial twist moments. LBP was associated with open class wool handlers spending more time in severe axially twisted postures. These findings suggest that skill-based training needs to be reviewed to reduce the quantity of axially twisted posture which may help reduce the prevalence of LBP in this workforce.

Keywords

Wool handling, work postures, skill, low back pain, cumulative loading.

1. Introduction

Wool is an important rural commodity manually harvested by shearers, sorted by wool handlers, pressed into 180 to 200kg bales for market purchase, and ultimately processed into yarn, cloth and other tertiary products. Recent investigation of skill and low back pain (LBP) in shearers demonstrates that skill can discriminate for differences in working posture and lifetime prevalence of occupational LBP. Shearers with a history of LBP also demonstrated significantly greater left medio-lateral and axial twist moments during their work tasks. Recommendations were made for industry training organisations to focus on reducing positional asymmetry from the flexed working postures of shearers.

There has been very little research on the injury risk or biomechanical, ergonomic or physiological demands of wool handlers (Gregory et al. 2009). Workplace observation (Figure 1) reveals a predominantly female workforce working in a variety of repetitive postures (often stooped) picking up in excess of 200 fleeces per day, each weighing between 5 to 10kg, and “throwing” these onto wool sorting tables where they are prepared, graded, and separated into various quality components. Gregory et al (2009) has recently investigated shoulder postures and loads of wool handlers and observed that highest skill (open class) spends significantly more time in neutral or mild shoulder postures. They suggest that risk of sustaining injury to the upper limb of the open class wool handler may be less than that of other skill levels and argue the potential importance of this observation for industry workforce training. However, no examination has been made of trunk postures and associated loads on the spine.

Insert Figure 1 about here

The aim of this study is to investigate the spinal loads and trunk postures of wool handling and to determine whether skill and/or LBP have any influence on these variables.

2. Method

2.1 Participants

Following ethical approval from the University of Otago Human Ethics Committee, 60 wool handlers (20 junior, 20 senior, and 20 open class) were recruited from two major wool harvesting competitions (Shearing Sports Inc. 2008) held in the South Island of New Zealand. Participant recruitment involved accessing competition schedules constructed for each skill level on the day of competition, and approaching wool handlers prior to competition until recruitment of 20 consenting wool handlers for each skill classification was completed. Following consent, participating wool handlers were surveyed for age (years), work experience (years), height (m), weight (kg), and the number of previous episodes of occupational LBP requiring clinical intervention (LBP-*Clin*) during their working lifetime.

During these competitions each wool handler's competitive score is formally judged on both the time taken to process the fleece and the quality of the processed fleece (Shearing Sports Inc. 2008, TECTRA NZ 2008). The wool handlers were recruited during the peak summer shearing season where there are considerable numbers of resident and itinerant workers harvesting wool and competing in regional wool handling competitions for peer and potential upward revision of skill. As this is common practice for most of the work force the participants in this study were accepted as a valid representation of wool handlers in New Zealand. The tasks undertaken during the competition were accepted as being representative of actual workplace conditions and while the emphasis is on two main parameters: quality of the sorted wool and the time taken to process and sort the wool this study only used the temporal and postural properties of the required tasks for analysis. Each wool handler was registered with Shearing Sports administration (Shearing Sports Inc, 2008; TECTRA NZ, 2008) and their previously judged ranking (junior, senior & open

class – based on the above parameters) used as the entry criteria for competition at that skill level.

Each wool handler was videotaped while processing three fleeces during their competitive heats. Their tasks involved gathering, preparing, grading, and separating the various wool components of the fleece – in a manner similar to that required in their working environment. They were videotaped from two different camera locations allowing full observation and recording of the wool handling tasks (Sutherland *et al.* 2007, Pal *et al.* 2010).

2.2 Video capture

Each videotape was captured to AVI digital format, with each wool handler's video file of 3 fleeces being sorted ranged from 4.5 to 9.0 minutes in duration dependent on level of skill. Each captured video trial was then analyzed using *3DMatch* (University of Waterloo, Waterloo, Ontario, Canada) at the accepted sampling rate of 3 frames/sec (Andrews and Callaghan, 2003).

2.3 Cumulative posture and force analysis

Cumulative moments about L4/5 were calculated by selecting previously validated sagittal, coronal and axial trunk posture bins (Sutherland *et al.* 2008) during each frame of the video, and included external 3D hand and upper limb forces, allowing the calculation of 3D moments about L4/5 joint. For a more detailed description of *3DMatch*, refer to Gregory *et al.* (2006). Each full fleece was accepted as 55.0N of load with 5.6kg being the average accepted weight of a cross bred fleece in New Zealand (Rowland 2006). Minor trimmings of wool undertaken during the skirting process were accepted as creating no more than 1.0N load, while wool containment baskets were accepted as a 10.0N force and the “belly” wool removed during the initial part of shearing generating no more than 5.0N. The moments calculated for

each frame were integrated over the entire duration of sorting the 3 fleeces in order to determine cumulative loads, which could then be extrapolated to an 8-hour working day. No account was taken of the inertial loads experienced during handling

2.4 Statistical analysis

All analyses were undertaken with the use of SPSS™ (V 16.0) statistical software. Skill was categorically classified (0 = junior; 1 = senior; 2 = open), as was history of LBP-*Clin* (0 = No; 1 = Yes). All other explanatory variables - personal, anthropometric, and work experience - were recorded as continuous data. The response variables were cumulative loads and postural data. The personal, anthropometric, and work related variables are summarised by skill level in Table 1, and explored for statistically significant differences between skill levels and LBP-*Clin* categories, and the postural and cumulative loading data are presented in Table 2. The influence of both skill and previous LBP-*Clin* on the percentage of cumulative time spent in each of 10 working postures and on each of 14 cumulative loads was explored firstly with a bivariate linear regression model. In order to optimally identify the influence of each explanatory variable the bivariate acceptance threshold into the multivariate model was contingent upon $p \leq 0.20$ (Altman 1996, pp. 349). As BMI, age and experience were also considered as potential confounders they were included in the multivariate analysis of each independent variable. The multivariate linear model used a dichotomous indicator variable (dummy variable) to represent each level of skill, and a dichotomous history of LBP-*Clin* (yes/no) as categorical explanatory variables. As wool handlers formally improve their productivity (tally) by undertaking skill training programmes it was considered that skill was the more important explanatory variable for inclusion in the stepwise model. The use of a stepwise model allowed us to focus on the effects of skill and LBP-*Clin* and their interaction as predictors of spinal loading and posture while spinal loading and posture were controlled for the inclusion of selected covariates as potential

confounding variables (Altman, 1966, pp. 325-326 & 340-351). This also allowed direct comparison with recently published shearing research that also explored the effects of skill and LBP-Clin. (Pal *et al* , 2010). The statistically significant results for these multivariate analyses are presented in Tables 3 and 4. For each model, each coefficient represents the difference between the mean of the group, represented by the particular term in the model and the mean of the referent group consisting of the aggregate of all groups not differentiated by the model.

3. Results

3.1 Anthropometric and work characteristics

The combined sample of 60 wool handlers had a mean age of 27.6 years, mean weight of 72.0kg, mean height of 1.65m, and mean BMI of 26.3kg/m² across all skill levels (Table 1). Fifty four (90%) of the sample were female and the 6 males were distributed across the 3 skill classifications (open = 3, senior = 2, junior = 1). Mean work experience was 9.4 years with a mean time-predicted daily tally of 231.5 fleeces. Twenty four (40%) of the wool handlers described having at least one previous episode of LBP-Clin. Although there were no significant associations for age, experience, skill, weight, BMI, with LBP-Clin; increased age ($p = 0.001$), height ($p = 0.004$), work experience ($p < 0.001$) and tally ($p < 0.001$) were significantly associated with the highest (open class) skill level.

Insert Table 1 about here

3.2 Mean group values for posture and cumulative load.

When aggregated across groups (Table 2) the predominant percentage of time (63.9%) was spent in mild flexion (from 25.0° to 45.0°), neutral lateral bend (79.9%), and neutral axial twist (73.5%). Mean cumulative compressive force and force weighted cumulative compression about L4/5 (Parkinson and Callaghan, 2007) were 48.7MN.s and 48.9MN.s respectively (Table 2). Cumulative joint anterior and reaction anterior shear were 2.5MN.s and 5.7MN.s with right and left medial to lateral shear of 0.5MN.s and 0.6MN.s. Cumulative joint posterior shear and reaction posterior shear were 47.7kN.s and 10.1kN.s respectively. Cumulative extensor moment was 2.1MNm.s, cumulative flexor moment 2.4kNm.s, cumulative right and left lateral bend moments were 0.2MNm.s and 0.2MNm.s while cumulative right and left axial twist moments were 26.6kNm.s and 28.5kNm.s.

Insert Table 2 about here

3.3 Effect of skill and LBP-Clin on cumulative percent time in working postures

Senior class wool handlers (Table 3) worked for a mean 5.4% less in mild flexion ($p = 0.029$) when compared to the open and junior class. Open class spent 5.1% less time ($p=0.004$) in neutral lateral bend and 4.0% more time ($p = 0.005$) in mild lateral bend, while senior class spent 10.9% more time in neutral and 10.2% less time in mild axial twist. Open class with a history of LBP-Clin spent 1.5% more working time in severe axial twist. These five models explain 8%, 14%, 13%, 10%, 9% and 31% of data variance for mild flexion, neutral lateral and mild lateral bend, and neutral, mild and severe axial twist respectively (Table 3).

Insert Table 3 about here

3.4 Effect of skill and LBP-Clin on cumulative load

Neither skill nor a previous history of LBP-Clin, nor the interaction between these two variables, had any statistically significant influences on either compressive or anterior/posterior shear cumulative forces. However the open class demonstrated significantly greater right and left medio-lateral reaction shear, right and left lateral bend moments, and right and left axial twist moments (Table 4) than the senior and Junior wool handlers. The models for these six variables respectively explain 14%, 8%, 10%, 15%, 17% and 14% of data variance. BMI, age and experience were also included in each of the multivariate load models but had no significant influence on the strength of these models.

Insert Table 4 about here

4. Discussion

The primary aim of this study was to explore how skill and a history of LBP-*Clin* affect cumulative trunk postures and low back loads of wool handlers. Descriptively there was a 9.1 year mean difference in age and a 4.5 year mean difference in work experience between junior and open class wool handlers. Despite a significant height difference for open class there were no differences in weight or BMI amongst the three skill levels, indicating little discriminative influence for these anthropometric variables. Consistent with industry advice (Rowland, 2006) and workplace observation, 90% (n = 54) of this sampled workforce were female and thus the small number of males (n = 6) distributed across the 3 skill levels could not provide any numerical strength to allow any comparative calculation of posture and load differences between males and females. Skill progression from junior to senior wool handler did not demonstrate any difference in estimated tally (fleeces handled per day) indicating the progression from junior to senior wool handler is predominantly based on quality score of the prepared fleece as judged by their peers. The progression to open class increased tally by an average of only 15 fleeces per day and suggests that quality fleece preparation is the paramount issue during wool handling tasks at least in the competition setting. Although there were observable differences in working lifetime prevalence of LBP-*Clin* particularly between junior (20.0%) and senior wool handler (50.0%) the progression to open class (45%) did not increase prevalence and indicates that exposure to risk factors is likely to be lower than that of progression to an open class (76%) shearer (Pal *et al.* 2010).

When compared to the working postures of shearers (Pal *et al.* 2010) wool handlers spend noticeably less cumulative time in severe trunk flexion, and more time in mild to severe lateral bend, and mild to severe axial twist. These differences directly influence the magnitude of cumulative loads at L4/5 where wool handler compression (50.0MN.s v 81.9MN.s) and anterior shear (2.4MN.s v 5.3MN.s) forces are also

noticeably less, reflecting the greater time spent by wool handlers in standing and less severe stooped postures. Not surprisingly the percentage of time that wool handlers work in a neutral to an extended posture generates minor but measurable posterior shear forces (47.7kN.s) and flexor moments (2.4kNm.s). The wool handlers' cumulative left (0.6MN.s v 33.72kN.s) and right (0.5MN.s v 16.4kN.s) medio-lateral shear forces, left (0.2MNm.s v 8.6kNm.s) and right (0.2MNm.s v 16.2kNm.s) lateral bend moments, and left (28.5kNm.s v 3.4kNm.s) and right (28.6kNm.s v 11.3kNm.s) axial twist moments are substantially greater than the shearers' (Pal *et al.* 2010) reflecting the much greater percentage of time wool handlers work in asymmetric yet less flexed postures.

A multivariate exploration of the effects of skill and previous LBP-*Clin* on wool handlers showed that senior class wool handlers spent significantly less time in mild flexion, significantly more time in neutral and significantly less time in mild axial twist. Open class wool handlers spent less time than senior and junior wool handlers in neutral and more time in mild lateral bend. While statistically significant, the percentage of variance explained by these models (from 8.0% to 14.0%) is not strong. Although the multivariate model did not accept LBP-*Clin* as a predictor for these postures open class wool handlers with a history of LBP-*Clin* spent significantly more time in severe axial twist postures in comparison to the referent group (all other wool handlers). Although this is only a 1.5% increase in time this interaction variable explains 31% of the variance for percentage time in severe axial twist and is a statistically strong ($p < 0.0001$) result. Post hoc analysis shows that 1.5% of an 8 hour work day is 7.2 minutes extra time spent in severe axial twist. This amount of increased time exposure in severe axial twist undertaken in various combinations of lateral bend and trunk flexion would be a plausible mechanism for creating increased risk of LBP in this workforce. While open class wool handlers generated significantly greater cumulative right and left reaction shear, right and left lateral bend and axial

twist moments about L4/5 the addition of LBP-*Clin* or its interaction with the three skill levels did not contribute any further statistical strength to the models. The contribution of the open class skill to the variance for these load models was not strong ranging from 8.0% to 17.0% (Table 4).

It is interesting to observe that bivariate analysis showed no relationship between skill and LBP-*Clin* and any of age, experience, height, weight and BMI. This is different from the observed significant relationship between skill and LBP in shearers (Pal *et al.* 2010). Although the medio-lateral and axial twist postures and loads were significantly greater for the wool handlers compared to the shearers the shearers had a substantially greater cumulative compressive and anterior shear force. Post hoc analysis also demonstrates a wool handler mean compressive force of 1691N and a 21N joint anterior shear force about L4/5, while for the shearers these were 2844N and 185N respectively. Thus the mean compressive and anterior shear forces for the shearers are 1.7 and 8.8 greater than that of the wool handlers and mean shearer compressive forces are within 83% of the NIOSH action limit of 3433N (Milosavljevic *et al.* 2004, Gregory *et al.* 2006).

These lesser cumulative loads and more variable postures for wool handlers are more likely to be within the safety tolerances of loading for the spine and are probably the main reason for the lower prevalence rate for open class wool handlers (45%) compared to open class shearers (76%) whose work generates greater spinal loads in more extreme flexed postures (Pal *et al.* 2010). Although these wool handler cumulative compressive loads are less than the shearers, it is important to note that they are still considerably greater than those described by Kumar (1990) and Norman *et al.* (1998) for at risk health care (15MN.s) and auto assembly workers (20MN.s) respectively (Gregory *et al.* 2006). While shearers appear to carry high risk for LBP-*Clin* that is associated with sustained posture, substantial cumulative loads,

increased medio-lateral shear forces and lateral bend and axial twist moments, pen class wool handlers carry risk for LBP-*Clin* that is more associated with excessive axial twist postures. Although the open class wool handlers had greater magnitudes for all asymmetric loads, these were not associated with LBP-*Clin*. It may also be that the numbers per skill classification were insufficient to discriminate any further relationships for the LBP-*Clin* variable.

An absence of LBP-*Clin* at least in open class wool handlers is associated with reduced amount of time in severe axial twist, so a focus on wool handler training to reduce the magnitude and time in axially twisted postures might be an important intervention. Although the results were not significant, attention to reducing lateral bend postures would also be a logical step since such postures will contribute to the observed differences in lateral bend moments and shear forces. Ways to reduce these extremes of axially twisted posture through wool handling instruction will ultimately determine the effect of such interventions on risk of LBP-*Clin* in this workforce.

This research has focused on how current skill ranking and a history of LBP-*Clin* are associated with observed trunk postures and spinal loads in a stepwise regression model. This cross-sectional design cannot determine causal links between postures and loads and the prevalence of LBP-*Clin*. In essence, this is a case-control study where those with a history of LBP-*Clin* demonstrate more extreme working postures and loads compared to those who have no such history. Although it appears logical that extremes of load and posture are predictors of LBP-*Clin*, it is also plausible (but considerably unlikely) that those who have had previous LBP-*Clin* have adapted to more extreme axially twisted working postures as a consequence of prior injury.. Although 60 participants took part, sub-classification by three levels of skill weakens the argument for strength of association between skill, posture and load. Similarly the

interaction between skill and LBP-*Clin* will also have a weaker argument for any observable effects and thus this study does not have the numerical strength for a robust and full examination of these associations. This cumulative postural and load analysis is based on a 4.5 - 9.0 min sample (dependent on skill level) and the results extrapolated to an 8 h working day. Thus the effects of fatigue and repetition on load and postural demands during a demanding set of work tasks have not been accounted for in this analysis. Hence external validity of this research to the standard working day of the wool handling workforce is unclear and will require a larger and powered sample in a longitudinal design using similar postural analysis. . Such research would help to validate the current results.

Sample size and the multivariate limitations of 24 postural and load response variables as well as 11 anthropometric and work-place explanatory variables mean that some of these significant results may be a chance occurrence. Given the multivariate stepwise testing of a limited number of variables that meet the $p < 0.20$ entry criteria some of the results may also be over-optimistic with regards to the strength of the model and its importance. In hindsight a larger sample of at least $n = 120$ would have satisfied recommended criteria ($n/10$) for the number of explanatory variables to fit a multivariate model. Given the sample size limitations ($n = 60$) we focussed on stepwise model that explored how skill and LBP-*Clin* were associated with trunk posture and spinal load and chose bivariate models to pre-select covariates. While this successfully limited the number of explanatory variables in each model it is acknowledged that some of the significant observations may be over-optimistic (Altman, 1966 pp. 349-351).

5. Conclusions

Open class wool handlers spend more time in asymmetric lateral bend and axial twist postures and logically generate greater medio-lateral forces and lateral bend and

axial twist moments in these postures. Dependent on skill level the working lifetime prevalence of LBP-*Clin* ranged from 25 (junior class) to 44% (open class) , considerably less than the 76% working lifetime prevalence for LBP-*Clin* for open class shearers. Open class wool handlers with a history of LBP-*Clin* work for longer periods of time in severe axial twist postures which may be the factor that places them at increased risk of low back injury. Although the cumulative compressive and shear forces (48.7MN.s and 2.5MN.s respectively) are substantially less than that generated by shearers, the cumulative compressive forces are still considerably greater than that described for other at-risk populations. While the results of this study cannot clearly associate an increasing prevalence of LBP-*Clin* with increasing skill it may be that the magnitude of these compressive and shear forces are still a component of low back injury in this workforce. These results suggest a focus on reducing the magnitude and duration of axially twisted work postures in the wool handling workforce will help reduce the risk and prevalence of occupational LBP.

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Figure 1. Various tasks associated with wool handling. A = Gathering wool from the shearing station. B = Sorting wool on the floor. C = Throwing an ~ 5.5kg fleece on to the wool sorting table. Note the variety of upright to stooped postures of the wool handlers compared to the fully stooped postures of the shearers.

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Table 4 Stepwise multivariate analyses for both wool handler skill level and LBP-*Clin* on cumulative loads at 95% CL

Table 1 - Summary of anthropometric and work characteristics of wool handlers by skill level

Characteristic	Junior (n=20)		Senior (n=20)		Open (n=20)		Total (n=60)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Mean age (yrs)	22.9	5.7	27.9	7.6	32.0	10.0	27.6	8.7
Mean height (m)	1.62	0.06	1.62	0.06	1.68	0.08	1.65	0.07
Mean mass (kg)	69.8	14.9	69.8	14.9	73.1	14.3	72.0	16.3
Mean BMI (kg/m ²)	26.6	5.6	26.6	5.6	25.8	4.6	26.3	5.3
Mean work experience (yrs)	4.9	5.1	9.3	6.0	14.2	8.4	9.4	7.6
Time predicted tally (fleeces)	218.5	23.1	216.9	14.6	259.0	13.9	231.5	26.2
LBP-Clin (%)	25 (n =5)		50 (n =10)		45 (n = 9)		40 (n = 24)	

Table 2 - Summary percentage of time spent in various postures and the cumulative loads for each wool handler skill level

	Junior (n=20)		Senior (n=20)		Open (n=20)		Total (n=60)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Posture	Percentage of time in posture							
Extension (>15°)	0.2	0.3	0.2	0.4	0.1	0.2	0.2	0.3
Neutral flexion (<25°)	8.4	8.4	10.3	6.6	7.2	3.7	8.6	6.6
Mild flexion (25 - 45°)	64.1	6.9	60.4	8.3	67.4	10.5	63.9	9.0
Severe flexion (>45°)	27.3	6.0	29.1	8.0	25.2	9.5	27.2	8.0
Neutral lat bend (<15°)	76.5	6.0	80.6	5.7	82.7	6.7	79.9	6.5
Mild lat bend (15 - 30°)	19.8	4.9	16.9	4.4	14.8	5.3	17.2	5.2
Severe lat bend (>30°)	3.7	1.6	2.6	2.3	2.5	2.3	2.9	2.1
Neutral ax twist (<15°)	68.7	13.1	80.8	17.7	70.9	17.5	73.5	16.8
Mild ax twist (15 - 30°)	29.7	12.3	18.7	17.4	28.2	17.2	25.6	16.3
Severe ax twist (>30°)	1.6	1.1	0.5	0.5	0.9	0.9	1.0	1.0
Type of Load	Cumulative forces							
Compression (MN.s)	50.0	9.7	50.1	10.6	45.9	5.6	48.7	9.0
Weighted compression (MN.s)	50.4	10.6	50.2	10.9	45.9	5.7	48.9	9.4
Joint anterior shear (MN.s)	2.5	0.6	2.6	0.7	2.5	0.4	2.5	0.6
Reaction anterior shear (MN.s)	5.7	1.4	5.9	1.7	5.4	0.9	5.7	1.4
Joint posterior shear (kN.s)	50.2	45.2	58.4	34.8	34.6	18.6	47.7	35.5
Reaction posterior shear (kN.s)	12.0	10.0	11.3	16.5	7.0	13.7	10.1	13.6
Right medio-lat reaction shear (MN.s)	0.6	0.3	0.4	0.2	0.5	0.2	0.5	0.3
Left medio-lat reaction shear (MN.s)	0.7	0.2	0.6	0.3	0.5	0.3	0.6	0.3
Extensor moment (MNm.s)	2.1	0.6	2.2	0.7	1.9	0.3	2.1	0.5
Flexor moment (kNm.s)	2.7	2.4	2.7	3.9	1.8	3.9	2.4	3.4
Right lateral bend moment (MNm.s)	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1
Left lateral bend moment (MNm.s)	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.1
Right axial twist moment (kNm.s)	33.4	15.5	22.6	7.6	24.0	6.3	26.6	11.5
Left axial twist moment (kNm.s)	34.8	11.5	26.6	11.9	24.2	9.7	28.5	11.8

Table 3 - Stepwise multivariate analyses for both wool handler skill level and LBP-Clin on cumulative percent time in working postures at 95% CL

Cumulative % time in:	Variable	Coeff.	Lower	Upper	Sig.	R ²
Mild Flexion	Referent Group	65.7	63.0	68.5		
	Senior class	-5.4	-10.17	-0.58	0.029	0.08
Neutral lateral bend	Referent Group	81.61	79.67	83.55		
	Open class	-5.10	-8.47	-1.74	0.004	0.14
Mild lateral bend	Referent Group	15.86	14.30	17.41		
	Open class	3.97	1.28	6.66	0.005	0.13
Neutral axial twist	Referent Group	69.81	64.72	74.91		
	Senior class	10.94	2.12	19.76	0.016	0.10
Mild axial twist	Referent Group	28.96	24.00	33.92		
	Senior class	-10.21	-18.81	-1.62	0.021	0.09
Severe axial twist	Referent Group	0.78	0.53	0.99		
	Open class x LBP	1.49	0.90	2.09	<0.0001	0.31

Note

a) all coefficients for each response variable come from the final model.

b) the explanatory variables are listed in order of stepwise selection

c) the R² values refer to the stepwise sequence of models.

Table 4 - Stepwise multivariate analyses for both wool handler skill level and LBP-Clin on cumulative loads at 95% CL

Cumulative load:	Variable	Coeff.	Lower	Upper	Sig.	R ²
Right medio-lateral reaction shear (kN.s)	Referent Group	0.42	0.35	0.50		
	Open class	0.20	0.07	0.33	0.004	0.14
Left medio-lateral reaction shear (kN.s)	Referent Group	0.55	0.47	0.63		
	Open class	0.15	0.01	0.29	0.033	0.08
Right lateral bend moment (kNm.s)	Referent Group	0.18	0.16	0.21		
	Open class	0.06	0.01	0.10	0.012	0.10
Left lateral bend moment (kNm.s)	Referent Group	0.14	0.12	0.17		
	Open class	0.07	0.03	0.12	0.002	0.15
Left axial twist moment (kNm.s)	Referent Group	23.28	19.94	26.63		
	Open class	10.09	4.30	15.89	0.001	0.17
Right axial twist moment (kNm.s)	Referent Group	25.40	21.91	28.89		
	Open class	9.36	3.32	15.40	0.003	0.14

Note

a) all coefficients for each response variable come from the final model.

b) the explanatory variables are listed in order of stepwise selection

c) the R² values refer to the stepwise sequence of models.