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# Testing of five exercises predicts absence or presence of low back pain in council workers



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# TITLE: Testing of five exercises predicts absence or presence of low back pain in council workers

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**ABSTRACT (word Count=287)**

**Objectives:** investigate the relationships between the ability/inability to perform five physical test-exercises and the presence and/or absence of low back pain (LBP).

**Setting:** regional Australian council training facility.

**Participants:** consecutive patients recruited during 39 back-educational programme classes (5-26 participants per class) for workers in general office/administration, parks/gardens maintenance, roads maintenance, library, child-care and management. Total sample (n=539) was reduced through non-consent and insufficient demographic data to n=422. Age 38.6+/-15.3 years, range 18-64 years, 73% male.

**Methods:** cross-sectional, exploratory, observational investigation. LBP presence was ascertained from a 3-response option questionnaire: 0=none/rarely (NO) 1=sometimes (Some), 2=mostly/always (Most). Statistical correlation was performed with the number of the five physical test-exercises the individual successfully performed: 1) extension-in- lying, 3-seconds; 2) 'toilet-squat'; feet flat, feet held, 3-seconds; 3) full-squat then stand-up, 5-times; 4) supine sit-up, knees flexed, 10-times; and 5) leg-extension, supine bilateral, 10-times.

**Interventions:** nil.

**Results:** for the group 'NO-Some', 94.3% completed 4-5 test-exercises, for 'With', 95.7% completed 0-1 test-exercises. The relationship between LBP presence and number of exercises performed was highly significant (X 2 (10) =300.61, p<0.001). Further, multinomial logistic regression predicting LBP (0=NO, 1=Some, 2=Most) from the number of exercises completed, substantially improved the model fit (initial-2LL=348.246, final-2LL=73.620, X 2 (2) =274.626, p<0.001). As the number of exercises performed increased, the odds of reporting 'Some-LBP' or 'Most-LBP' were 0.34 and 0.17. Consequently, the ability to complete more exercises substantially reduced the likelihood of reported LBP.

**Conclusion:** the ability to complete/not-complete five physical test-exercises correlated statistically and significantly with a higher LBP absence/presence in a general working population. Training individuals to complete such exercises could facilitate reductions in LBP. However, causality cannot be inferred. Randomized trials are recommended to establish the potential efficacy of physical exercise-based approaches considering these five selected exercises for predicting and managing LBP.

**Strengths and limitations of this study**

- This was a prospective  cross-sectional, exploratory, observational investigation
- It is representative of a general working population as it contained diverse occupations, ages, both genders and a consecutive sample from regional council workers during an educational workshop
- The sample had continuity and subsequently a degree of homogeneity enabling a degree of generalization
- The sample size was sufficient to ensure adequate power
- The functional exercises were not tailored for exercise dose and specificity for age and gender

## INTRODUCTION

Low back pain (LBP) is among the most prevalent occupational disorders in working populations under 45 years of age[1]. Further, LBP can affect up to 10 percent of the world's population at any given time[2]. When disability adjusted life years (DALY's) are considered, LBP is amongst the leading global causes of disease burden[3]. However, LBP is also distinctive in that limited progress has occurred in identifying effective strategies for its prevention and effective treatment[4-6] despite the recognition and identification of factors that predispose or correlate to the future presence of LBP[7-9]. The capacity to predict problematic LBP has several promising protocols. These include questionnaire-based biopsychosocial screening methods[10-12] and movement patterns or maladaptive postures[13]. There are, however, few or no validated physiological or physical screening tests to predict problematic LBP[14,15], including measures of disuse or changed levels of physical conditioning[16].

The economic burden of LBP leads to reduced efficiency and productivity from the individual to the organisational and even community level. The burden compounds direct and indirect costs to private, professional and governmental medical care stakeholders, compensation related to wages, worker recruitment and training as well as productivity losses[17,18]. These factors are further inflated by social consequences[19,20] to the individual, their family, the community and society as a whole[21,22]. Despite the many recognised risk factors that predispose an individual to LBP[23,24], the trends in business processes in work settings coupled with technology advancement over recent decades, has seen occupational and social changes that influence the requirements or personal choices to adopt static postures[25,26]. In contrast, manual workers have gained both advantages and disadvantages from these trends with a net result that their occupational postures and loads in areas such as maintenance and building have remained consistent[27,28].

The direction of recent and ongoing research on LBP prevention and recurrence has focused on non-modifiable factors and long-term exposures. This research has included: medical investigative relationships such as radiological[29,30] or physiological findings[31-33], that have produced mixed results, even from the same study[34]; along with biopsychosocial considerations[35-39]; or a mixture of these[7,8,40]. In contrast, modifiable factors[41,42] that have significant influence on LBP morbidity and symptomology of affected populations[43] and are recognised as potential contributors to preventing LBP[23], have received limited research. Such factors include the way we move[28,44], the physiological loads incurred during movement[45], and exercise capacity[46]. The need to consider modifiable factors is supported by recent research[47,48] that has reinforced the relationship between dynamic physical tests, self-reported LBP and reduced function[49,50].

As a consequence of the knowledge gap in the research of these modifiable factors, there is a need for an observational study in a representative working population to ascertain and analyze the relationship between the reported presence of LBP symptoms and the individuals' physical functional movement capabilities. One such group is council workers, which includes both genders, a wide age range and diverse occupational loads[51] with manual and sustained stationary and sedentary postures[52]. Cross-sectional analysis of these working groups can be representative of general working populations and provide insight into the capacities and abilities that may or may not lead to the presence or risk of LBP[53,54].

This observational study investigated a population of council workers as a representative sample of the general working population and evaluated whether or not the ability, or not, to perform five back-related exercises could determine or predict the presence or absence of LBP. Analysis of the findings may indicate what movements, or lack of movements, might be associated with the presence and/or absence of LBP. The outcomes may contribute to both the understanding of the relevance of functional movement and exercises as well as provide direction for future prospective studies. Such studies could, subsequently, identify specific functional movements in order to provide a structured exercise regime that reduces the presence of LBP and its predisposition, prevents future episodes and enhances physical performance.

## METHODS

A cross-sectional, exploratory, observational investigation was initiated over a period of 28 months in a population of employees with the Sunshine Coast Regional Council in Queensland, Australia. Workers from a convenience sample were consecutively recruited during 39 annual back educational programme classes. Occupational categories included: general office worker, parks and gardens maintenance, roads maintenance, library, child-care and management groups. Class participant numbers ranged from 5-26, with a total sample of n=539. This number was reduced through non-consent, and failure to provide sufficient demographic data to a total of n=422, age 38.6+/-15.3 years, range 18-64 years, 73% male.

### Test Activities

All participants were asked to perform five functional movement exercises during the educational session under supervision of the educational session leader, a physiotherapist with a post-graduate certification in Sports Physiotherapy and McKenzie Manual Diagnostic Therapy (MDT). Each exercise was designated as completed by the physiotherapist in conjunction with a majority of the group participants, as this was a team building exercise as well as an educational session and all participants were familiar with each other in a daily working environment:

1) EIL: extension in lying, held for 3 seconds;
2) SITUP: sit-up from supine with knees flexed and the arms passing the knees to or beyond the elbow whilst exhaling, performed 10 times;
3) LEGEXT: supine bilateral leg extension starting with the knees over the umbilicus and feet then extending until the heels touched the ground with the knees in full extension, performed 10 times;
4) SQUAT: ‘toilet squat’ - barefoot, feet and heels flat, hands holding feet, held for 3 seconds; and
5) RISEUP: full squat and stand-up, performed 5 times with the head rising before the buttocks.

### Questionnaire

Each participant also completed a questionnaire: ‘How often do you have low back pain?’ with three-response options: ‘rarely/none’, ‘sometimes’ or ‘always/mostly’, with classification determined by the respondents and interpreted within their own context of how they perceived the symptoms. These response options, as a 3-point scale, are a condensed classification of the World Health Organisation's five point classification of 'never', 'rarely', 'sometimes', 'often', and 'very often'[55]. The response options were scored on a 0-1-2 scale[56,57] and classified as: 0=rarely/none (NO), 1=sometimes (Some), 2=always/mostly (Most). The responses were initially dichotomized to the presence or not of the 'condition in question'[55], namely LBP for this study. Those who responded 0=rarely/none were classified 'NO-LBP', not having LBP; those responding 1=sometimes, 2=always/mostly were classified as 'LBP'. This 'LBP' group was, subsequently, further dichotomized into 'Some' and 'Most' to sub-categorize the severity of LBP being present in their lives 'sometimes' or 'most of/all the time' (Some/Most)[55]. The response options were, subsequently, correlated with the number of exercises the individual was able to perform successfully.

Ethics approval was given by the Educational Committee of the Sunshine Coast Council. Data was collected whilst the primary author was under a Research Fellowship at James Cook University (JCU), with a given Ethics approval H1673, and during PhD Studies at the University of the Sunshine Coast where the existing JCU approval was further ratified (HREC: S04/48/MC and HREC:08/10).

Statistical analysis was performed using the Statistical Package for Social Science version 23.0 (SPSS 23.0) for Windows with significance set at $p<0.05$.

**RESULTS**

For descriptive purposes, a cross-tabulation of LBP (0=none, 1=Some, 2= Most) and the number of exercises accomplished is presented in Table 1. Participants with NO-LBP (85.5%) were able to complete at least four exercises, and less than 3% of all participants were able to complete one or no exercises. Participants with "Some" LBP (12.9%) were able to complete four or more exercises, and 23.7% were able to complete one or none of the exercises. Of participants with more significant LBP (Most), only 10.5% were able to complete four or more exercises, while 74.3% were able to complete only one or none of the exercises. A Pearson Chi-square test was performed demonstrating a significant relationship between the variables of 'LBP' and 'number of exercises performed' ($X^2_{(10)} = 300.61$, $p<0.001$).

A multinomial logistic regression predicting LBP (0, 1, 2, with 0 being the reference group) from the count of exercises that could be completed (EX_SUM, ranging from 0-5), showed a strong effect (initial-2LL = 348.246, final-2LL = 73.620, $X^2_{(2)} = 274.626$, $p < 0.001$; Table 2). As presented in Table 3, as EX_SUM increased one exercise, the odds of reporting some LBP or mostly LBP dropped substantially: Odds Ratio = 0.34 (95%CI = 0.27, 0.44) and 0.17 (95%CI = 0.12, 0.23), for LBP = 1 and 2, respectively. No curvilinear effect was present, nor was any effect of gender.

A second multinomial logistic regression entered the five exercise variables individually, rather than entering the total number accomplished, to test whether particular tests were individually diagnostic (predictive) of LBP. As shown in Table 4, overall the effect was similarly strong[58] (initial-2LL = 429.93, final -2LL = 147.40, $X^2_{(2)} = 282.53$, $p<0.001$). As Table 5 presents, most exercises were individually predictive of LBP (when LBP=1, EIL was not uniquely predictive with all other variables in the equation). All others were statistically significant (all $p$ <0.002) with odds ratios ranging in magnitude from 0.21 to 0.38. For "Most" LBP (LBP=2), all exercises were significant independent predictors of LBP (all $p$<0.017), with odds ratios ranging from 0.09 to 0.35.

**DISCUSSION**

Though it has been noted previously that a relationship exists between dynamic physical tests and self-reported LBP and reduced function[49], this area of research has fallen from favor in recent decades[35-39]. The move towards research considerations of physiological and radiological findings[7,8,40] and those of biopsychosocial relationships have been preferred[4,59]. The earlier work of Grönblad et al.[49] showed three physical exercises (repetitive sit-ups, squats, and EIL/back-arch) had a positive correlation with the presence of LBP. This study builds on the research as it expands the number of test exercises. It also shows a higher statistical correlation between physical exercise tests and LBP than found previously. The effect sizes found were substantial[58], indicating that for each increase in the number of exercises accomplished, the odds of having some LBP are about one-third less than that of those accomplishing one fewer exercises.

This study has clearly shown that the presence of LBP is significantly statistically related to the ability to perform the exercise tasks utilised. All exercises were uniquely predictive of LBP (except EIL where LBP=1). Additionally, the total number of exercises completed was strongly related to LBP. Both the relevance of a gender effect and potential curvilinear effects were tested as per the accepted recommendation[58] and found to have no effect on the results. In other words, those able to perform more exercises were substantially less likely to report LBP of either category. These findings with robust effect sizes, and the 95% confidence intervals[58], demonstrate a substantial relationship. Consequently, these exercises could be used clinically to diagnose the potential severity of LBP, and perhaps severity of impairment. However, because this was an observational study, it is not possible to indicate whether training individuals to complete these five exercises could facilitate reductions in LBP. From the author's clinical management protocol it can be speculated that this appears to be possible.

The ability to perform repeated squatting has been demonstrated to be inversely related to LBP as the balance between hip and lumbar spine mobility must be met[60], i.e., better squatting ability results in reduced LBP[50]. This research group also found that females were more susceptible to LBP if they had lower capacity on physical performance tests, a finding not evident in this study. It has also be noted that excess or prolonged squatting can have a negative effect through the increased presence of LBP[61]; effectively a verification of the Arndt Schultz Law where a small amount of something is good and necessary, but too much is detrimental[62]. Similarly, EIL as an exercise is beneficial with a known capacity to facilitate maintenance of the lumbar lordosis[63]. There is a direct link between a reduced lordosis and the presence or incidence of LBP[64]. Maintenance of the lordosis is essential for disc centralisation both as a management strategy and as a preventative exercise[63,65]. However, this exercise alone was not statistically significant in predicting LBP.

Back endurance testing has been confirmed as a statistically accurate screening test for LBP where poor performance in static back endurance correlates to higher incidence[66-68]. However, the EIL test is a passive test not using the back extensor muscles but the arms as the prime mover. It may be that individuals with excessive lumbar extensor activation and substitution during this test may confound the results. Further, some studies have indicated that measures of trunk muscle strength in isolation are not related to LBP symptoms and functional ability. The functional tests such as EIL and sit-up have been shown by some researchers to have stronger associations with perceived disability than isokinetic tests[69-71].

LBP is increasing in industrial societies with a cause that is unclear. Consequently, preventative strategies can play a key role in reducing societal and individual demands on the health care system and societal support. Physical functional tests, especially those emphasized in this study, are directed primarily toward the abdominal and lumbo-pelvic muscles and their coordinated activity. The coordination and interplay between the various muscle groups is recently defined as 'integral' in the understanding of lumbar stability as a complex integrated model[45]. Personal efficiency in physical self-test completion can act as a screening methodology for individuals at risk of musculoskeletal disorders such as LBP. It is, however, important that the method of test performance is considered and noted with critical efficacy. It has been shown that there is no relation between the sit-up test performance and reported LBP when the feet are held down[72]. The action facilitates increased hip flexor muscle action over abdominal muscle participation. Alternative actions that preference the abdominal muscles, such as a partial curl-up test with the feet free, similar to our study, are more highly correlated to LBP[73-75].

Effective back function requires coordination between multiple structures including neural integrity. Consequently, the task specific related nature of such a coordinated activity should be considered within the perspective of daily life, prevention strategies, and treatment approaches as well as performance enhancement procedures. This study incorporated tests that stress different muscles and related regions; actions that are more related to human function and movement and consistent with historically recognized patterns and activities[44]. The EIL and sit-up tests are both unloaded in the initiation phase. The EIL involves the hip and lumbar spine though prime movers are in the arms and stabilisation is through the thoracic and scapula region enabling a predominantly passive lumbar extension. The sit-up test recruits the abdominal muscles but also requires trunk and upper body involvement as well as hip and pelvic interplay. The squat test is in a loaded position and requires coordination between hip, knee, and lumbo-pelvic complex. Any imbalance in the muscular action, joint and soft tissue movement, and neural conduction of any regions affects the quality of motion in the functional test[73,44].

**Study strengths and weaknesses**

Strengths of this study include the prospective nature, the sample being workers of both sexes, with diverse age groups and occupations but within one organisation and geographical region. This enabled a continuity and degree of homogeneity in the sample that strengthened the statistical findings. The sample size was sufficient to ensure adequate power and representation of the constructs under consideration. The findings were statistically substantial in the effect size and the determined relationship between the physical tests and the presence of LBP.

Study weaknesses are that other functional exercises might have been alternatively chosen and that exercise dose and specificity for age and gender were not used. These may be confounding factors. However, the statistical findings showed that the exercises chosen were indeed relevant and that neither gender nor age influenced the results.

**Future research**

Determining the exercises indicative of LBP is imperative for the processes of diagnosis and setting a discharge goal in the clinical setting. However this knowledge does not indicate the optimal manner to address the pain, overall quality of movement and any other compromised capacity associated with LBP. The next step in this line of inquiry would therefore be to determine which intervention regimen (or structured combination of) could improve the ability to harmoniously perform and maintain the said exercises in an optimized and scalable manner. To do so would require a prospective, longitudinal study with both symptomatic and non-symptomatic LBP patients. One of the challenges in assessing efficacy would be the thorough standardisation of the tests, considering the possibility of gender variation in the number of repetitions or degree of movement, noting that males tend to be stronger and females more flexible. Further, the measurement at baseline, during and following intervention would need to be accurate and highly sensitive in the measure of function and capacity. These factors may require a combination of physical tests as well as patient-reported outcome tools, where the currently preferred tools may not be sufficient or require sample sizes and a number needed to treat that would prolong the duration of the study. Recently devised computer based measures, such as decision support systems (CDSS)[76] and adaptive technology (CAT)[77] could prove beneficial for such an approach.

**CONCLUSION**

In a group of 422, predominantly male, Australian Council workers presenting in a mixed general working population, the ability to complete or not-complete five simple functional exercises showed a significant and meaningful clinical correlation with the presence or absence of LBP. Those able to perform more exercises were significantly less likely to report the presence of LBP either sometimes or most of the time. Conversely, those unable to perform any or one exercise were more likely to report the presence of LBP most of the time. These findings could not only be useful for diagnostic purposes, but we hypothesised that training pain-free individuals to be able to complete the five exercises could facilitate prevention of LBP in a general working population. Further, that a graded introduction of these exercises as part of a supervised rehabilitation programme, for individuals recovering from an episode of LBP, may facilitate overall recovery and reduce recurrence.  A prospective trial to investigate this hypothesis is to be initiated.

## Author Contribution

**Charles Philip Gabel –** provided the concept and design of the study; acquisition of participants and data, assisted data analysis and interpretation, drafting of manuscript and critical revising

**Hamidreza Mokhtarinia** - provided drafting and critical revising of manuscript

**Jonathan Hoffman** - provided drafting and critical revising of manuscript

**Jason Osborne -** provided manuscript design; participants and data analysis and interpretation, drafting of manuscript and critical revising.

**Liisa Laakso -** provided data interpretation, drafting and critical revising of manuscript

**Markus Melloh -** provided concept and design input, assisted data analysis and interpretation, drafting of manuscript and critical revising.



## Competing Interests

- Nil

## Funding Sources

- Nil

## Data sharing statement

- The authors agree to make available data for sharing including through the Dryad depository

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**LIST OF TABLES:**

Table 1: Exercises accomplished as a function of LBP

| Number Exercises completed | | LBP 0 | LBP 1 | LBP 2 | Total |
|---|---|---|---|---|---|
| 0 | Count | 1 | 8 | 33 | 42 |
| | % within LBP | 0.6% | 5.6% | 31.4% | 10.0% |
| 1 | Count | 4 | 26 | 45 | 75 |
| | % within LBP | 2.3% | 18.1% | 42.9% | 17.8% |
| 2 | Count | 5 | 32 | 12 | 49 |
| | % within LBP | 2.9% | 22.2% | 11.4% | 11.6% |
| 3 | Count | 15 | 45 | 4 | 64 |
| | % within LBP | 8.7% | 31.3% | 3.8% | 15.2% |
| 4 | Count | 58 | 20 | 6 | 84 |
| | % within LBP | 33.5% | 13.9% | 5.7% | 19.9% |
| 5 | Count | 90 | 13 | 5 | 108 |
| | % within LBP | 52.0% | 9.0% | 4.8% | 25.6% |
| Total | Count | 173 | 144 | 105 | 422 |
| | % within LBP | 100.0% | 100.0% | 100.0% | 100.0% |

Table 2: Model summary entering only count of exercises completed (EX_SUM)

**Model Fitting Information**

| Model | Model Fitting Criteria | Likelihood Ratio Tests | | |
|---|---|---|---|---|
| | -2 Log Likelihood | Chi-Square | df | Sig. |
| Intercept Only | 348.246 | | | |
| Final | 73.620 | 274.626 | 2 | .000 |

Table 3: Parameter estimates

| LBP[a] | | B | Std. Error | Wald | df | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower Bound | Upper Bound |
| 1.0 some | Intercept | 3.622 | .469 | 59.645 | 1 | .000 | | | |
| | EX_SUM | -1.069 | .121 | 77.475 | 1 | .000 | .343 | .271 | .436 |
| 2.0 mostly | Intercept | 4.628 | .497 | 86.653 | 1 | .000 | | | |
| | EX_SUM | -1.784 | .158 | 127.031 | 1 | .000 | .168 | .123 | .229 |

a. The reference category is: .0 none.

Table 4: Model summary when five exercises entered individually

**Model Fitting Information**

| Model | Model Fitting Criteria | Likelihood Ratio Tests | | |
|---|---|---|---|---|
| | -2 Log Likelihood | Chi-Square | df | Sig. |
| Intercept Only | 429.927 | | | |
| Final | 147.397 | 282.530 | 10 | .000 |

Table 5: Parameter estimates when exercises entered individually

**Parameter Estimates**

| LBP[a] | | B | Std. Error | Wald | df | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower Bound | Upper Bound |
| 1.0 | Intercept | 3.320 | .520 | 40.719 | 1 | .000 | | | |
| | EX1_EIL | -.148 | .401 | .136 | 1 | .713 | .863 | .393 | 1.894 |
| | EX2_situp | -1.326 | .284 | 21.827 | 1 | .000 | .266 | .152 | .463 |
| | EX3_legext | -1.101 | .362 | 9.246 | 1 | .002 | .332 | .164 | .676 |
| | EX4_squat | -.959 | .298 | 10.337 | 1 | .001 | .383 | .214 | .688 |
| | EX5_riseup | -1.540 | .413 | 13.929 | 1 | .000 | .214 | .096 | .481 |
| 2.0 | Intercept | 4.415 | .539 | 67.084 | 1 | .000 | | | |
| | EX1_EIL | -1.050 | .440 | 5.698 | 1 | .017 | .350 | .148 | .829 |
| | EX2_situp | -2.010 | .429 | 21.977 | 1 | .000 | .134 | .058 | .310 |
| | EX3_legext | -1.666 | .432 | 14.854 | 1 | .000 | .189 | .081 | .441 |
| | EX4_squat | -1.532 | .414 | 13.672 | 1 | .000 | .216 | .096 | .487 |
| | EX5_riseup | -2.392 | .456 | 27.495 | 1 | .000 | .091 | .037 | .224 |

a. The reference category is: .0.

BMJ Open

# Testing of five exercises predicts absence or presence of low back pain in council workers

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# TITLE: Testing of five exercises predicts absence or presence of low back pain in council workers

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**ABSTRACT (word Count=276)**

**Objectives:** investigate the relationships between the ability/inability to perform five physical test-exercises and the presence or absence of low back pain (LBP).

**Setting:** regional Australian council training facility.

**Participants:** consecutive participants recruited during 39 back education classes (8-26 participants per class) for workers in general office/administration, parks/gardens maintenance, roads maintenance, library, child-care and management. Total sample (n=539) was reduced through non-consent and insufficient demographic data to n=422. Age 38.6+/-15.3 years, range 18-64 years, 67.1% male.

**Methods**: cross-sectional, exploratory, observational investigation. LBP presence was ascertained from a three-response option questionnaire: 0=none/rarely (NO) 1=sometimes (Some), 2=mostly/always (Most). Statistical correlation was performed with the number of the five test-exercises the individual successfully performed: 1) extension-in-lying, 3-seconds; 2) 'toilet-squat'; feet flat, feet touched, 3-seconds; 3) full-squat then stand-up, 5-times; 4) supine sit-up, knees flexed, 10-times; and 5) leg-extension, supine bilateral, 10-times.

**Interventions:** nil.

**Results:** for the group 'NO-Some', 94.3% completed 4-5 test-exercises, for 'With', 95.7% completed 0-1 test-exercises. The relationship between LBP presence and number of exercises performed was highly significant ($X^2_{(10)}$=300.61, $p$<0.001). Further, multinomial logistic regression predicting LBP (0=NO, 1=Some, 2=Most) from the number of exercises completed, substantially improved the model fit (initial-2LL=348.246, final-2LL=73.620, $X^2_{(2)}$=274.626, $p$<0.001). As the number of exercises performed increased, the odds of reporting 'Some-LBP' or 'Most-LBP' dropped substantially (odds ratios of 0.34 and 0.17, respectively).

**Conclusion**: the ability to complete/not-complete five test-exercises correlated statistically and significantly with a higher LBP presence/absence in a general working population. Training individuals to complete such exercises could facilitate reductions in LBP incidence however, causality cannot be inferred. Randomized trials are recommended to establish the potential efficacy of exercise-based approaches, considering these five selected exercises, for predicting and managing LBP.

**Strengths and limitations of this study**

- This was a cross-sectional, exploratory, observational investigation
- It is representative of a general working population as it contained diverse occupations, ages, both genders and a consecutive sample from regional council workers during an educational workshop
- The sample had continuity and subsequently a degree of homogeneity enabling a degree of generalization to be inferred
- The sample size was sufficient to ensure adequate power
- The functional exercises were not tailored for either exercise dose or specificity for age and gender

Key Words: Low back pain, functional exercise, preventative medicine, rehabilitation medicine

## INTRODUCTION

Low back pain (LBP) is among the world's most prevalent occupational disorders in working populations[1] and major global public-health concerns[2], affecting 12 percent of the world's population at any given time[2,3] with lifetime prevalence at 84% and chronicity around 23%[2]. When disability adjusted life years (DALY) are considered, LBP is a leading global cause of disease burden[3]. However, LBP is distinctive in that limited progress has occurred in identifying effective prevention strategies and treatments[4,5], despite established recognition and identification of factors that predispose or correlate to future LBP[6,7]. Predicting problematic LBP has several promising protocols including questionnaire-based biopsychosocial screening methods[8,9] and movement patterns or maladaptive postures[10]. There are, however, few or no validated physiological or physical predictive screening tests[11] including measures of disuse or changed levels of physical conditioning[12].

The LBP economic burden leads to reduced efficiency and productivity by individuals, organisations and the community compounding in/direct costs to private, professional and governmental medical care stakeholders, wages compensation, worker recruitment and training and productivity losses[13]. These factors are further inflated by social consequences to individuals, families, communities, and general society[14,15]. Despite many recognised risk factors that predispose individuals to LBP[16], business process trends in work settings coupled with recent technology advancement, has seen occupational and social changes that influence the requirements or personal choices to adopt static postures[17]. In contrast, manual workers have gained both advantages and disadvantages, with occupational postures and loads in areas such as maintenance and building having remained consistent[10,18].

The direction of contemporary research on LBP prevention and recurrence has focused on non-modifiable factors and long-term exposures. These include: medical investigative relationships such as radiological[19,20] or physiological findings[21-23], that have produced mixed result even from the same study[24]; and biopsychosocial considerations[25-28]; or a mixture of these[6,7]. In contrast, modifiable factors[29,30] including movement patterns[10,31], physiological loads[32], and exercise capacity[33,34] receive limited attention yet they significantly influence LBP morbidity and symptomology[1,2], being recognized as potentially able to prevent LBP[16].

LBP disorders are multi-factorial with individual symptomology influenced by various patho-anatomical, physical, neuro-physiological, psychological, and social contributors[10,32]. Consequently, voluntary activities that involve lumbo-pelvic specific exercises are effective in primary and secondary LBP prevention[35]. Such exercises improve fitness and occupational status by diminishing disability and problem severity[31,36] and may counter selective atrophy of Type II fibers found in the presence of pathological changes[37,38]. However, muscle recruitment remains predominantly neural-based during rehabilitation with psychological adaptations derived from improved motivation and pain tolerance[39]. The conundrum remains that LBP reduces functional capacity, fitness and general health status (GHS), including depression[40] while low capacity from pathology, injury, GHS or sedentary lifestyle increases the risk of LBP[41]. The need to consider modifiable factors is supported by recent research[42] that confirmed the relationship between dynamic physical tests, self-reported LBP and reduced function[34,43].

Existing research has a knowledge-gap for modifiable factors demonstrating a need for observational studies in representative working populations. Addressing this gap will assist in identifying the relationship between LBP symptoms and individual physical functional movement capabilities. A representative group, with strong indicators of generalizability, is council workers. The group includes diversity of gender, age and occupations with variance in manual and sustained loads[44] and stationary and sedentary postures[45]. Cross-sectional analysis of these groups is a starting point in implied generalization and provides insight into the capacities and abilities that may lead to the presence or risk of LBP[46,47].

This observational study investigated council workers, as an implied representative general working population sample, and evaluated whether the ability, or not, to perform five back-related exercises could determine or predict the presence or absence of LBP. We hypothesized that the test-exercises would demonstrate the ability of the lumbar spine to: *move* in a controlled manner through normal range as a complex multi-segmental functional activity with coordinated biomechanical and neuromuscular components; and be *stabilized*, as part of the lumbo-pelvic-hip complex, through motor control of the integrated muscular system[32,48]. Consequently, the ability to perform the exercises would correlate with lower self-reported LBP.

Once established, analysis of the findings might indicate what movements, or lack thereof, might be associated with the presence and/or absence of LBP for individuals in different occupational and physical activity settings. The outcomes might contribute to understanding the relevance of functional movement and exercises in relation to LBP, and provide a direction for future prospective studies. Such studies could identify specific functional movements for specific tasks or risk groups then provide structured exercise regimens that might reduce LBP and its predisposition.

## METHODS

A cross-sectional, exploratory, observational investigation was initiated over a period of 28 months in a population of employees with the Sunshine Coast Regional Council in Queensland, Australia. Workers from a convenience sample were consecutively recruited during 39 annual back educational programme classes of two hours duration. A total of 21 separate occupational categories were recorded and an additional 'Other' category for miscellaneous non-specified occupations. Class participant numbers ranged from 8-26, with a total sample of n=539. Only participants who consented were included. Data was excluded if there was insufficient demographic information. Consequently, the sample was reduced to a total of n=422, age 38.6±15.3 years, range 18-64 years, 67.3% male (see Table 1). Males were predominant in manual occupational roles including maintenance and construction, while females were predominant in carer and resource management including child-care, community services, library and records roles.

Table 1: Sample demographics

| Age (years) | 38.6±15.3 | Range:18-64 | | | |
|---|---|---|---|---|---|
| | | | | | |
| **Occupation (Job)** | **Total** | **Total %** | **Male** | **% Total** | **% Male** |
| Archives | 10 | 2.4% | 4 | 0.9% | 40.0% |
| Airport maintenance | 3 | 0.7% | 3 | 0.7% | * 100.0% |
| Child Care | 36 | 8.5% | 3 | 0.7% | ° 7.5% |
| Community Services | 34 | 8.1% | 1 | 0.2% | ° 3.3% |
| Construction | 22 | 5.2% | 22 | 5.2% | * 100.0% |
| Corporate Records | 7 | 1.7% | 2 | 0.5% | ° 28.6% |
| Emergency Room | 21 | 5.0% | 15 | 3.6% | * 71.4% |
| Fleet and Plant | 16 | 3.8% | 16 | 3.8% | 100.0% |
| Information systems | 5 | 1.2% | 2 | 0.5% | 40.0% |
| Information Technology | 11 | 2.6% | 9 | 2.1% | * 81.8% |
| Infrastructure | 12 | 2.8% | 8 | 1.9% | 66.7% |
| Library | 46 | 10.9% | 15 | 3.6% | ° 32.6% |
| National Parks | 13 | 3.1% | 12 | 2.8% | * 92.3% |
| Operations Maintenance | 7 | 1.7% | 6 | 1.4% | * 85.7% |
| Operations Management | 11 | 2.6% | 7 | 1.7% | 63.6% |
| Parks Bushland Services | 69 | 16.4% | 68 | 16.1% | * 98.6% |
| People & Organisational | 1 | 0.2% | 0 | 0.0% | ° 0.0% |
| Roads Management | 65 | 15.4% | 64 | 15.2% | * 98.5% |
| Strategy & Planning | 11 | 2.6% | 7 | 1.7% | 63.6% |
| Treasury and Risk | 2 | 0.5% | 2 | 0.5% | * 100.0% |
| Water Services | 18 | 4.3% | 17 | 4.0% | * 94.4% |
| Other | 2 | 0.5% | 0 | 0.0% | ° 0.0% |
| **Total** | n=422 | 100.0% | Male= 283 | Male= 67.1% | |

* Indicates Male >67%; ° Indicates Female >67%

**Test Activities**

The test exercises were selected based on having significant elements of lumbo-pelvic-hip function and being recognized for reducing symptomology or risk of LBP. The five selected exercises were chosen to represent a balanced variation of functions required for normal daily activities[31]. Three exercises previously investigated, 'repeated sit-ups', 'repeated squats', and 'extension in lying' (EIL)[34], showed a positive correlation with LBP and were, consequently, included. The sustained squat and leg extension exercises, respectively require functional movement[32,48] and a predominantly isometric abdominal co-activation[49], which occur or simulate daily, occupational and sports activities[50]. Other exercises were considered but excluded, such as active spine flexion which has shown poor correlation with LBP[51].

All participants were volunteers and performed five functional movement exercises during an educational session with other attendees, supervised by the session leader, a Sports Physiotherapist Certified in McKenzie Manual Diagnostic Therapy. The instructions for exercise justification, instructions, completion and reliability are detailed in Figure 1. Intra-observer reliability for screening tests movement instruction is recognised as being moderate-high[52].

**Questionnaire**

During the educational sessions each participant completed a self-report questionnaire: 'How often do you have low back pain?' with three-response options: 'rarely/none', 'sometimes' or 'always/mostly', with the time frame and symptoms interpreted within their life context. This 3-point scale is condensed from the World Health Organisation's five-points: 'never', 'rarely', 'sometimes', 'often', and 'very often'[53]. The three-point response provides an 'intermediate' option, which is critical from psychological and statistical perspectives. Psychologically, three cognitive perspectives facilitate response accuracy by reducing cognitive load[54,55] which improves precision and consistency[56]. Statistically, responses were coded on a 0-1-2 scale[57,58]: 0=rarely/none (No LBP), 1=sometimes (Some LBP), 2=always/mostly (Most LBP).

*Ethics approval* was from the Educational Committee of the Sunshine Coast Council with data collected under James Cook University, H1673 and the University of the Sunshine Coast HREC:S04/48/MC and HREC:08/10.

Statistical analysis was performed using SPSS 23.0 for Windows with significance set at $p<0.05$. Following preliminary data screening to ensure data quality (e.g., no aberrant values), an initial cross-tabulation of LBP (0=none, 1=some, 2=most) and number of exercises was performed to explore whether self-reported LBP was related to the number of exercises completed. A chi-square test evaluated whether the null hypothesis (that the number of exercises completed would be consistent across LBP groups) was tenable or able to be rejected.

A multinomial logistic regression was performed, exploring whether the number of exercises (EX_SUM) predicted LBP (categorized as 0, 1, 2) to test the null hypothesis that the probability or odds of being classified into LBP groups are not different because of number of exercises performed; and if rejected, to quantify the change in odds or probability of LBP as it relates to number of exercises performed. This test also allowed us to evaluate whether participant gender interacted with EX_SUM, or whether there were non-linear effects present. Regression diagnostics for this analysis (e.g., residuals, influence) were examined to ensure no aberrant cases were inappropriately influencing the analysis[59]. None were identified.

Finally, if the null hypothesis from the prior multinomial logistic regression was rejected, we performed a second multinomial logistic regression on LBP entering each exercise as a predictor (rather than simply the count of number of exercises completed) to examine whether all exercises were uniquely predictive or whether some subset of exercises were more predictive than others. All five exercises were entered simultaneously, allowing for examination of unique effects of each variable controlling for all other variables in the equation. Regression diagnostics were examined and no aberrant cases were identified[59].

**Patient and public involvement**

The research question and outcome measures were developed over a three year period during delivery of a work site back care education program to the local council. This involved both formal and informal work related discussions with attendees and management enabling the program and exercise selection to be progressively modified. This informed program progression, specifically the exercises and their relation to the presence or not of LBP, ensured the priorities of exercise simplicity for the identification and prevention of LBP. The experience gained by this process refined the program and the selected preferences providing the statistical relation between the exercises and the presence or not of LBP. Patients were recruited by choice of opting out or providing informed consent to have measured their LBP status, by self-report questionnaire, and their performance on the five exercises. Permission to conduct the study was approved by the management and the separate Universities Ethics committees. The results of each session were disseminated immediately to each participant, and after the initial three years of the program and pilot statistical analysis, the statistical relation was related and discussed as part of the program. The authors wish to thank the participants and the management for their contributions and for enabling the program and the recording of the findings to be completed and statistically analyzed.

**RESULTS**

For descriptive purposes, a cross-tabulation of LBP (0=none, 1=Some, 2=Most) and the number of exercises accomplished is presented in Table 2. Most participants reporting no LBP could complete most exercises. For individuals with no LBP, 85.5% could complete at least four exercises. Exercise completion dropped significantly for participants with "Some" LBP. In this group, only 22.9% were able to complete four or more exercises, and for participants with "Most" LBP, only 10.5% were able to complete four or more exercises. Analyzing participants in each category who failed to complete more than one exercise, the pattern is reversed. Only 2.9% of those with no LBP had trouble completing more than one exercise, while 23.7% of those with "some LBP" and 74.3% of those with "most LBP" were unable to complete more than one. A Pearson Chi-square test was performed demonstrating a significant relationship between the variables of 'LBP' and 'number of exercises performed' ($X^2_{(10)}$=300.61, $p$<0 .001).

Table 2: Exercises accomplished as a function of LBP

| Number Exercises completed | | LBP 0 None | LBP 1 Some | LBP 2 Most | Total |
|---|---|---|---|---|---|
| 0 | Count | 1 | 8 | 33 | 42 |
| | % within LBP | 0.6% | 5.6% | 31.4% | 10.0% |
| 1 | Count | 4 | 26 | 45 | 75 |
| | % within LBP | 2.3% | 18.1% | 42.9% | 17.8% |
| 2 | Count | 5 | 32 | 12 | 49 |
| | % within LBP | 2.9% | 22.2% | 11.4% | 11.6% |
| 3 | Count | 15 | 45 | 4 | 64 |
| | % within LBP | 8.7% | 31.3% | 3.8% | 15.2% |
| 4 | Count | 58 | 20 | 6 | 84 |
| | % within LBP | 33.5% | 13.9% | 5.7% | 19.9% |
| 5 | Count | 90 | 13 | 5 | 108 |
| | % within LBP | 52.0% | 9.0% | 4.8% | 25.6% |
| Total | Count | 173 | 144 | 105 | 422 |
| | % within LBP | 100.0% | 100.0% | 100.0% | 100.0% |

A multinomial logistic regression predicting LBP (0, 1, 2, with 0 being the reference group) from the count of exercises that could be completed (EX_SUM, ranging from 0-5), showed a strong effect (initial-2LL=348.246, final-2LL=73.620, $X^2_{(2)}$=274.626, $p$<0.001; Table 3).

Table 3: Model summary entering only count of exercises completed (EX_SUM)

**Model Fitting Information**

| Model | Model Fitting Criteria | Likelihood Ratio Tests | | |
|---|---|---|---|---|
| | -2 Log Likelihood | Chi-Square | df | Sig. |
| Intercept Only | 348.246 | | | |
| Final | 73.620 | 274.626 | 2 | .000 |

As presented in Table 4, as EX_SUM increased incrementally, the odds of reporting some LBP or most LBP reduced substantially: Odds Ratio=0.34 (95%CI=0.27, 0.44) and 0.17 (95%CI=0.12, 0.23), for LBP=1 and 2, respectively. No curvilinear effect was present, nor any gender effect.

Table 4: Parameter estimates

| LBP[a] | | B | Std. Error | Wald | df | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower Bound | Upper Bound |
| 1.0 some | Intercept | 3.622 | .469 | 59.645 | 1 | .000 | | | |
| | EX_SUM | -1.069 | .121 | 77.475 | 1 | .000 | .343 | .271 | .436 |
| 2.0 most | Intercept | 4.628 | .497 | 86.653 | 1 | .000 | | | |
| | EX_SUM | -1.784 | .158 | 127.031 | 1 | .000 | .168 | .123 | .229 |

a. The reference category is: .0 none.

A second multinomial logistic regression with the five exercise variables entered individually, rather than entering the total number accomplished, evaluated whether tests were individually predictive of LBP. As shown in Table 5, overall the effect was similarly strong[59] (initial-2LL=429.93, final-2LL=147.40, $X^2_{(2)}$=282.53, $p$<0.001).

Table 5: Model summary when five exercises entered individually

**Model Fitting Information**

| Model | Model Fitting Criteria | Likelihood Ratio Tests | | |
|---|---|---|---|---|
| | -2 Log Likelihood | Chi-Square | df | Sig. |
| Intercept Only | 429.927 | | | |
| Final | 147.397 | 282.530 | 10 | .000 |

As Table 6 presents, most exercises were individually predictive of LBP (when LBP=1, EIL was not uniquely predictive with all other variables in the equation). All others were statistically significant ($p$<0.002) with odds ratios ranging in magnitude from 0.21 to 0.38. For “Most” LBP (LBP=2), all exercises were significant independent predictors of LBP (all $p$<0.017), with odds ratios ranging from 0.09-0.35.

Sensitivity for the first analysis (percent of participants with LBP correctly classified into LBP category) was 82.3%, and specificity (percent of participants with no LBP classified as such) was 85.6%. The positive predictive value (true positives divided by true and false positives) was 89.1%; and negative predictive value (true negatives divided by true and false negatives) was 77.1%. Sensitivity for the second analysis was 79.5%, and specificity was 87.9%. Positive predictive value was 90.4%, and negative predictive value was 74.9%.

Table 6: Parameter estimates when exercises entered individually

**Parameter Estimates**

| LBP[a] | | B | Std. Error | Wald | df | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|---|---|
| 1.0 | Intercept | 3.320 | .520 | 40.719 | 1 | .000 | | | |
| | EX1_EIL | -.148 | .401 | .136 | 1 | .713 | .863 | .393 | 1.894 |
| | EX2_situp | -1.326 | .284 | 21.827 | 1 | .000 | .266 | .152 | .463 |
| | EX3_legext | -1.101 | .362 | 9.246 | 1 | .002 | .332 | .164 | .676 |
| | EX4_squat | -.959 | .298 | 10.337 | 1 | .001 | .383 | .214 | .688 |
| | EX5_riseup | -1.540 | .413 | 13.929 | 1 | .000 | .214 | .096 | .481 |
| 2.0 | Intercept | 4.415 | .539 | 67.084 | 1 | .000 | | | |
| | EX1_EIL | -1.050 | .440 | 5.698 | 1 | .017 | .350 | .148 | .829 |
| | EX2_situp | -2.010 | .429 | 21.977 | 1 | .000 | .134 | .058 | .310 |
| | EX3_legext | -1.666 | .432 | 14.854 | 1 | .000 | .189 | .081 | .441 |
| | EX4_squat | -1.532 | .414 | 13.672 | 1 | .000 | .216 | .096 | .487 |
| | EX5_riseup | -2.392 | .456 | 27.495 | 1 | .000 | .091 | .037 | .224 |

a. The reference category is: .0.

We also took in to consideration a simple analysis relating the presence or absence of LBP to exercises. This approach, combining two groups of LBP (some, mostly) into one category potentially reduces the goodness of the analysis by combining two different groups into one heterogeneous group. If the two groups were distinct, this would increase error variance and decrease the power and informativeness of the analyses. Ancillary binary logistic regression analyses therefore tested the null hypothesis that the two LBP groups were similar. Results of this analysis, which predicted LBP (i.e., some vs. mostly) showed that EX_SUM was significantly related to this outcome (initial-2LL=339.05, final-2LL=284.96, $X^2_{(1)}$=54.09, $p$<0.001), leading us to reject the null hypothesis and assert that these two groups are significantly distinct.

## DISCUSSION

Previous research demonstrated a relationship between dynamic physical tests, self-reported LBP and reduced function[34]. However, such research has been neglected in recent decades[25-28] as focus shifted towards physiological and radiological findings[6,7] and biopsychosocial attributes[4]. Grönblad et al.[34] showed three physical exercises (repetitive sit-ups, squats, and EIL) had a positive correlation with LBP. Our current study builds on this research as it expands the number of test exercises. It also shows a higher statistical correlation between physical exercise tests and LBP than found previously. These findings with robust effect sizes, and the 95% confidence intervals[59], demonstrate a substantial relationship. Our results indicate that for each increase in the exercise number accomplished, the odds of having some LBP were about one-third less than that of those participants accomplishing one fewer exercise.

This study clearly showed that the presence of LBP is significantly statistically related to the ability to perform the chosen exercise tasks. All exercises were uniquely predictive of LBP (except EIL where LBP=1). The total number of exercises completed was strongly related to LBP. The relevance of a gender effect and potential curvilinear effects was tested as per the accepted recommendation[59] and found to have no effect on the results. Effectively, those able to perform more exercises were substantially less likely to report LBP. Consequently, these exercises have the potential to be investigated in future research in terms of the ability to provide a clinical diagnosis related to the potential or risk that an individual may development LBP, and perhaps even future impairment.

The ability to perform repeated squatting has been demonstrated to be inversely related to LBP as the balance between hip and lumbar spine mobility must be met, i.e. better squatting ability is associated with reduced LBP[43]. These researchers found females more susceptible to LBP if they had lower physical performance capacity, a finding not evident in our study. Further, excess/prolonged squatting has a negative effect through increased LBP[60]. Similarly, EIL is beneficial and facilitates lumbar lordosis maintenance[61]. There is a direct link between a reduced lordosis and LBP[62]. Lordosis maintenance is essential for disc symptomology centralisation for LBP management and preventative exercise strategies[61,63]. The exercise alone was not predictive of LBP.

Back endurance testing is a statistically accurate LBP screening test as poor performance in static back endurance correlates to higher incidence[64,65]. However, EIL is a passive test using the arms as the prime mover. It is possible that individuals with excessive lumbar extensor activation and substitution during this test may confound the results. Further, some studies have indicated that trunk muscle strength measures in isolation are unrelated to LBP symptoms and functional ability .

Exercise therapy is an efficient, cost-effective LBP management strategy[66,67] but there is no evidence to support any single exercise. Coordinated muscle activity around the lumbo-pelvic region is considered vital for mechanical spinal stability[32,68]. Several rehabilitative "stabilization exercise" approaches emphasize retraining functional movement patterns, rather than focusing on specific muscles[31,69,70]. The tests we chose activate and challenge the global muscles of the abdomen and trunk, the "abdominal brace" mechanism[71], and their ability to act and interact in a synergistic and functional manner. We screened functional test performance where the aim was assessing participants' functional status regardless or not of LBP and its known or potential cause. As LBP increases in industrial societies with no clear cause it is important to consider risk factors of physical workload and awkward posture[4] as well as preventative strategies that may play a key role in reducing health care system demands and societal support. The exercise tests we used primarily address abdominal and lumbo-pelvic muscles, and their coordination with lower limb muscle activity and maintenance of balance. This coordination was recently defined as 'integral' in understanding lumbar stability as a complex integrated model[32]. Personal efficiency in physical self-test completion can act as a screening methodology for individuals at risk of LBP. It is, however, important that the method of test performance is considered e.g., there is no relation demonstrated between sit-up performance and LBP when the feet are held[72]. This action preferences hip flexor activity over abdominal participation. Alternative actions that preference abdominal muscles, e.g. partial curl-up, are more highly correlated to LBP[73,74]. Our results provide guidance for future work that may contribute to a comprehensive screening, prevention and management approach to LBP.

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**Study strengths and limitations**

The strengths of this study include the cross-sectional nature, the sample including both genders, diverse age groups and occupations but within one organisation and geographical region. This enabled continuity, and a degree of homogeneity in the otherwise varied sample, that strengthened the statistical findings with respect to general working populations. The sample had adequate power and representation of the constructs under consideration. The findings were statistically substantial in the effect size and the determined relationship between the physical tests and the presence of LBP. Causality, however, cannot be inferred from this study.

Other exercise tests may have similar utility. In choosing the exercise tests, we did not consider exercise dose and specificity for age and gender and these may be confounding factors. However, the statistical findings showed that the exercises chosen were relevant and that neither gender nor age influenced the results.

Other potential limitations were the use of a self-assessed diagnosis as participants were not physically examined and the reported LBP was their interpretation of the area 'above the buttocks to the region of waist'. Additionally, that participant self-reported gender was the only potential moderator or confounding variable included in the data. As noted above, gender itself was not a significant predictor in any analysis ($p$>0.80), and thus not included in analyses reported. We were unable to test for a significant interaction between gender and exercises (e.g., EX_SUM) due to quasi-complete separation in the data. However, a trend appeared where the effects for males were *slightly* stronger. This might represent a direction for future research within larger samples, or simply a sample artefact.

**Future research**

Determining the exercises indicative of LBP is imperative for diagnosis and setting discharge goals, the next step is to determine which intervention regimen/s could improve the ability to harmoniously perform and maintain the exercises in an optimized and scalable manner. This would require a prospective, longitudinal study with symptomatic/non-symptomatic LBP patients. Challenges in assessing efficacy are test-standardisation plus gender variation in repetitions number or degree of movement as males are generally stronger and females more flexible. Further, all measurements at baseline and follow-up must be accurate and sensitive. Consequently, a combination of physical tests and patient-reported outcomes are needed, where many currently preferred tools may not be sufficiently sensitive[23].

Furthermore, this study had limited demographic variables. Consequently, future research may consider moderating factors aside from gender. Perhaps age is a differential consideration. However, the very strong analyses effects observed and that our lack of explicitly modeling these hidden variables would have biased the results toward the null, it is unlikely that unobserved variables are true confounders, but might clarify and increase the sensitivity of some effects if modeled. As an observational study, however, it was not possible to indicate whether gradually training individuals to complete these five exercises could facilitate reductions in LBP. From the several authors clinical management protocol it may be speculated that this appears possible.

## CONCLUSION

In a group of 422, predominantly male, Australian Council workers presenting in a mixed general working population, the ability to complete or not-complete five simple functional exercises showed a significant and meaningful clinical correlation with the presence or absence of LBP. Those able to perform more exercises were significantly less likely to report the presence of LBP either sometimes or most of the time. Conversely, those unable to perform any or one exercise were more likely to report the presence of LBP most of the time. These findings could not only be useful for diagnostic purposes, but we hypothesised that training pain-free individuals to be able to complete the five exercises on a regular basis could facilitate prevention of LBP in a general working population. Further, that a graded introduction of these or similar exercises as part of a supervised rehabilitation programme, for individuals recovering from an episode of LBP, may facilitate overall recovery and reduce recurrence. A prospective trial to investigate this hypothesis is to be initiated.

## Figure Legend

**Figure 1: Test Activities - Exercise Descriptor and Reliability**

**Author Contribution**

**Charles Philip Gabel –** provided the concept and design of the study; acquisition of participants and data, assisted data analysis and interpretation, drafting of manuscript and critical revising

**Hamidreza Mokhtarinia** - provided drafting and critical revising of manuscript

**Jonathan Hoffman** - provided drafting and critical revising of manuscript

**Jason Osborne -** provided manuscript design; participants and data analysis and interpretation, drafting of manuscript and critical revising.

**Liisa Laakso -** provided data interpretation, drafting and critical revising of manuscript

**Markus Melloh -** provided concept and design input, assisted data analysis and interpretation, drafting of manuscript and critical revising.

**Competing Interests**

- Nil

**Funding Sources**

- Nil

**Data sharing statement**

- The authors agree to make available data for sharing including through the Dryad depository

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**Figure 1: Test Activities - Exercise Descriptor and Reliability**

| Test # | Title | Justification for inclusion | Instructions to participants | Successful completion | Test reliability |
|---|---|---|---|---|---|
| 1 | EIL - Extension in Lying - held for 3 seconds | maximal lumbar extension simulates the physical properties of normal spinal movements[1,2] because limited extension[3] is related to LBP[4], clinically impaired spinal control[5], and may inhibit symptom centralization[6,7] | lying face down, hands beneath shoulders, forehead on the floor. Keep your pelvis on the floor, breathe in, press with your arms, raise your chest off the ground, breathing out and increasing the movement until your arms are straight. Hold three seconds | hips/pelvis remain in contact with floor, arms fully extended | ICC=0.95-0.98[8] |
| 2 | SITUP: sit-up from supine performed 10 times | through range, active concentric and eccentric trunk flexion control enables the lumbar spine to dissipate and distribute load and provides a stable area for performing limb and trunk activities[2,9-11] | lying face-up on the floor, knees bent, feet flat, arms straight and hands on thighs. Breathe in, slowly sit-up whilst breathing out, move the elbows to touch your knees, rolling forward and up from the floor in a continuous movement, until everything above the buttocks is not touching the ground and your elbows reach your knees. Lower down in a continuous movement reversing the motion without falling or dropping while breathing out. Repeat 10 times | no sudden/rapid inertial motion, trunk not held rigid, feet remain on floor, elbows reach/pass the knees, body doesn't drop down | ICC=0.995[12] |
| 3 | LEGEXT: supine bilateral leg extension performed 10 times | abdominal muscles are used predominantly isometrically to stabilize the body during this exercise[13,14] and relevant to performing many household, occupational and sports activities[13]. The exercise provides co-activation significantly greater than in sit-ups/curl[16] enabling testing of rectus abdominis muscle and the internal and external oblique muscle activation[14] reducing LBP risk when part of a motor control exercise program[17] | lying on back on floor breathing in, head in contact or elevated, knees bent and above the umbilicus, lower back contacts the floor, hands by side or under buttocks. Both legs are straightened, knees straightening until heels touch floor while breathing out. Small amounts of knee flexion are permitted. Return legs to the start position. Repeat 10 times | back and buttocks contact the floor, heels touch the ground, hands remain in start position | [double] leg lower (ICC=0.81-1.00)[15] ICC=0.98[18]; active single leg raise $ICC_{1,3}$=0.95-0.97[19]; abdominal muscle % "time active" is 54-86%[14] |
| 4 | SQUAT: 'toilet squat' barefoot, hands touch feet, held for 3 seconds | squatting is frequently used and associated with many ADLs. It requires optimal lumbar flexion control to ensure normal spinal movements are maintained[1,2], and shear-forces/lateral-movement are minimalized[20]. Squatting is a complex multi-segmental functional movement requiring coordinated biomechanical and neuromuscular components involving the leg and pelvic joints and muscles, respiratory system, with prime-mover muscle activation not significantly affected by common variations in kinetic chain continuity[21]. A semi-rigid spine eliminates planar motion but retains antero-posterior spinal integrity, as spinal flexion generally increases with hip flexion and the associated synergistic lumbar-pelvic action[20,22] which reduces the risk of LBP[23] | standing comfortably, feet shoulder-width apart, arms loosely at your side. Breathe in, slowly squat, as though using a squat-toilet, allow the arms to move forward and hands touch the feet. Hold for 3 seconds | pelvis is lowered, heels/feet flat, fingers touch the feet | Intra-rater Kappa=0.81-1.00 when tested alone[24]; ICC>0.60 within a multi-exercise screen[25] and ICC=0.81[26] |
| 5 | RISEUP: full squat and stand-up, performed 5 times | repeated squatting is functional and readily transfers to multiple ADLs. It requires coordinated prime-mover muscle activation and endurance[21] being the technique of choice for manual handling as net moments, muscle forces and internal spinal loads related to compression and shear force are reduced[27]. Reduces LBP risk and is critical for normal spinal movement[1,2] | complete the squat position described, then rise to full standing with the head rising at the slightly before or at the same time as the buttocks. Repeat 5 times, a short rest is permitted | full squat action as above; on rise trunk rises before buttocks/pelvis, i.e. knee extension before hip | ICC=0.61-0.80, standard error of measurement<3%[28] |

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Figure 1: Test Activities - Exercise Descriptor and Reliability

326x120mm (144 x 144 DPI)

https://www.strobe-statement.org/?id=available-checklists

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

| | Item No | Recommendation |
|---|---|---|
| ✓ **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found |
| **Introduction** | | |
| ✓Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported |
| ✓Objectives | 3 | State specific objectives, including any prespecified hypotheses |
| **Methods** | | |
| ✓Study design | 4 | Present key elements of study design early in the paper |
| ✓Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection |
| ✓Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants |
| ✓Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable |
| ✓Data sources/ ✓measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group |
| ✓Bias | 9 | Describe any efforts to address potential sources of bias |
| ✓Study size | 10 | Explain how the study size was arrived at |
| ✓Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why |
| ✓Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding |
| | | (*b*) Describe any methods used to examine subgroups and interactions |
| | | (*c*) Explain how missing data were addressed |
| | | (*d*) If applicable, describe analytical methods taking account of sampling strategy |
| | | (*e*) Describe any sensitivity analyses |
| **Results** | | |
| ✓Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed |
| | | (b) Give reasons for non-participation at each stage |
| | | (c) Consider use of a flow diagram |
| ✓Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders |
| | | (b) Indicate number of participants with missing data for each variable of interest |
| ✓Outcome data | 15* | Report numbers of outcome events or summary measures |
| ✓Main results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included |
| | | (*b*) Report category boundaries when continuous variables were categorized |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period |
| ✓Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses |
| **Discussion** | | |
| ✓Key results | 18 | Summarise key results with reference to study objectives |

| | | |
|---|---|---|
| ✓Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias |
| ✓Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence |
| ✓Generalisability | 21 | Discuss the generalisability (external validity) of the study results |
| **Other information** | | |
| ✓Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based |

*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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# Does the performance of five back-associated exercises relate to the presence of low back pain? A cross-sectional observational investigation in regional Australian council workers

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**TITLE:**

Does the performance of five back-associated exercises relate to the presence of low back pain? A cross-sectional observational investigation in regional Australian council workers.

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**ABSTRACT (word Count=276)**

**Objectives:** investigate the relationships between the ability/inability to perform five physical test-exercises and the presence or absence of low back pain (LBP).

**Setting:** regional Australian council training facility.

**Participants:** consecutive participants recruited during 39 back education classes (8-26 participants per class) for workers in general office/administration, parks/gardens maintenance, roads maintenance, library, child-care and management. Total sample (n=539) was reduced through non-consent and insufficient demographic data to n=422. Age 38.6+/-15.3 years, range 18-64 years, 67.1% male.

**Methods**: cross-sectional, exploratory, observational investigation. LBP presence was ascertained from a three-response option questionnaire: 0=none/rarely (NO) 1=sometimes (Some), 2=mostly/always (Most). Statistical correlation was performed with the number of the five test-exercises the individual successfully performed: 1) extension-in-lying, 3-seconds; 2) 'toilet-squat'; feet flat, feet touched, 3-seconds; 3) full-squat then stand-up, 5-times; 4) supine sit-up, knees flexed, 10-times; and 5) leg-extension, supine bilateral, 10-times.

**Interventions:** nil.

**Results:** for the group 'NO-Some', 94.3% completed 4-5 test-exercises, for 'With', 95.7% completed 0-1 test-exercises. The relationship between LBP presence and number of exercises performed was highly significant ($X^2_{(10)}$=300.61, $p$<0.001). Further, multinomial logistic regression predicting LBP (0=NO, 1=Some, 2=Most) from the number of exercises completed, substantially improved the model fit (initial-2LL=348.246, final-2LL=73.620, $X^2_{(2)}$=274.626, $p$<0.001). As the number of exercises performed increased, the odds of reporting 'Some-LBP' or 'Most-LBP' dropped substantially (odds ratios of 0.34 and 0.17, respectively).

**Conclusion**: the ability to complete/not-complete five test-exercises correlated statistically and significantly with a higher LBP presence/absence in a general working population. Training individuals to complete such exercises could facilitate reductions in LBP incidence however, causality cannot be inferred. Randomized trials are recommended to establish the potential efficacy of exercise-based approaches, considering these five selected exercises, for predicting and managing LBP.

**Strengths and limitations of this study**

- This was a cross-sectional, exploratory, observational investigation
- It is representative of a general working population as it contained diverse occupations, ages, both genders and a consecutive sample from regional council workers during an educational workshop
- The sample diversity with continuity and subsequent homogeneity enabled generalization to be inferred
- The sample size was sufficient to ensure adequate power
- The functional exercises were not tailored for either dose or specificity for age or gender

Key Words: Low back pain, functional exercise, preventative medicine, rehabilitation medicine

## INTRODUCTION

Low back pain (LBP) is among the world's most prevalent occupational disorders in working populations[1] and major global public-health concerns[2,3], and worsening due to increasing age and populations[4]. It affects 12 percent of the world's population at any given time[2,5] with lifetime prevalence at 84% and chronicity around 23%[2]. When disability adjusted life years (DALY) are considered, LBP is a leading global cause of disease burden[5,6]. However, LBP is distinctive in that limited progress has occurred in identifying effective prevention strategies and treatments[7,8], and is remains nearly impossible to provide absolute certainty of a specific nociceptive cause and only a small proportion have a recognised pathological cause[3,6]. This is despite established recognition and identification of factors that predispose or correlate to future LBP[6,9,10]. Predicting problematic LBP has several promising protocols including questionnaire-based biopsychosocial screening methods[11-13] and movement patterns or maladaptive postures[14]. There are, however, few or no validated physiological or physical predictive screening tests[15] including measures of disuse or changed levels of physical conditioning[16].

The LBP economic burden leads to reduced efficiency and productivity by individuals, organisations and the community compounding in/direct costs to private, professional and governmental medical care stakeholders, wages compensation, worker recruitment and training and productivity losses[5,17]. These factors are further inflated by social consequences to individuals, families, communities, and general society[18,19]. Despite many recognised risk factors that predispose individuals to LBP[10,20], business process trends in work settings coupled with recent technology advancement, has seen occupational and social changes that influence the requirements or personal choices to adopt static postures[21]. In contrast, manual workers have gained both advantages and disadvantages, with occupational postures and loads in areas such as maintenance and building having remained consistent[14,22].

The direction of contemporary research on LBP prevention and recurrence has focused on non-modifiable factors and long-term exposures. These include: medical investigative relationships such as radiological[23,24] or physiological findings[25-27], that have produced mixed result even from the same study[28]; and biopsychosocial considerations[29-32]; or a mixture of these[9-11]. In contrast, modifiable factors[33,34] including movement patterns[14,35], physiological loads[36], and exercise capacity[37,38] receive limited attention yet they significantly influence LBP morbidity and symptomology[1,2], being recognized as potentially able to prevent LBP[11,20].

LBP disorders are multi-factorial with individual symptomology influenced by various patho-anatomical, physical, neuro-physiological, psychological, and social contributors[3,14,36]. Consequently, voluntary activities that involve lumbo-pelvic specific exercises are effective in primary and secondary LBP prevention[39]. Such exercises improve fitness and occupational status by diminishing disability and problem severity[35,40] and may counter selective atrophy of Type II fibers found in the presence of pathological changes[41,42]. However, muscle recruitment remains predominantly neural-based during rehabilitation with psychological adaptations derived from improved motivation and pain tolerance[43]. The conundrum remains that LBP reduces functional capacity, fitness and general health status (GHS), including depression[44] while low capacity from pathology, injury, GHS or sedentary lifestyle increases the risk of LBP[45]. The need to consider modifiable factors is supported by recent research[46] that confirmed the relationship between dynamic physical tests, self-reported LBP and reduced function[38,47].

Existing research has a knowledge-gap for modifiable factors demonstrating a need for observational studies in representative working populations[3,6,11]. Addressing this gap will assist in identifying the relationship between LBP symptoms and individual physical functional movement capabilities. A representative group, with strong indicators of generalizability, is council workers. The group includes diversity of gender, age and occupations with variance in manual and sustained loads[48] and stationary and sedentary postures[49]. Cross-sectional analysis of these groups is a starting point in implied generalization and provides insight into the capacities and abilities that may lead to the presence or risk of LBP[50,51].

This observational study investigated council workers, as an implied representative general working population sample, and evaluated whether the ability, or not, to perform five back-related exercises could determine or predict the presence or absence of LBP. We hypothesized that the test-exercises would demonstrate the ability of the lumbar spine to: *move* in a controlled manner through normal range as a complex multi-segmental functional activity with coordinated biomechanical and neuromuscular components; and be *stabilized*, as part of the lumbo-pelvic-hip complex, through motor control of the integrated muscular system[36,52]. Consequently, the ability to perform the exercises would correlate with lower self-reported LBP.

Once established, analysis of the findings might indicate what movements, or lack thereof, might be associated with the presence and/or absence of LBP for individuals in different occupational and physical activity settings. The outcomes might contribute to understanding the relevance of functional movement and exercises in relation to LBP, and provide a direction for future prospective studies. Such studies could identify specific functional movements for specific tasks or risk groups then provide structured exercise regimens that might reduce LBP and its predisposition.

## METHODS

A cross-sectional, exploratory, observational investigation was initiated over a period of 28 months in a population of employees with the Sunshine Coast Regional Council in Queensland, Australia. Workers from a convenience sample were consecutively recruited during 39 annual back educational program classes of two hours duration. The first two classes provided a pilot study (n=33) to estimate effect size and 'Bootstrap analysis' ensured the effect size had reasonable confidence. Standard power estimation calculations on the range of anticipated effect sizes provided minimum sample size goals. The participants were recruited from a range occupations, ages and locations provide participants that reasonably reflect the population of interest. This representative population minimized selection bias, however potential bias remained from non-response, the volunteer consent requirement and ascertainment bias. A total of 21 separate occupational categories were recorded and an additional 'Other' category for miscellaneous non-specified occupations. Class participant numbers ranged from 8-26, with a total sample of n=539. Only participants who consented were included. Data was excluded if there was insufficient demographic information. Consequently, the sample was reduced to a total of n=422, age 38.6±15.3 years, range 18-64 years, 67.3% male (see Table 1). Males were predominant in manual occupational roles including maintenance and construction, while females were predominant in carer and resource management including child-care, community services, library services and records roles.

Table 1: Sample demographics

| **Age (years)** | 38.6±15.3 | Range:18-64 | | | |
|---|---|---|---|---|---|
| | | | | | |
| **Occupation (Job)** | **Total** | **Total %** | **Male** | **% Total** | **% Male** |
| Archives | 10 | 2.4% | 4 | 0.9% | 40.0% |
| Airport maintenance | 3 | 0.7% | 3 | 0.7% | * 100.0% |
| Child Care | 36 | 8.5% | 3 | 0.7% | ° 7.5% |
| Community Services | 34 | 8.1% | 1 | 0.2% | ° 3.3% |
| Construction | 22 | 5.2% | 22 | 5.2% | * 100.0% |
| Corporate Records | 7 | 1.7% | 2 | 0.5% | ° 28.6% |
| Emergency Room | 21 | 5.0% | 15 | 3.6% | * 71.4% |
| Fleet and Plant | 16 | 3.8% | 16 | 3.8% | 100.0% |
| Information systems | 5 | 1.2% | 2 | 0.5% | 40.0% |
| Information Technology | 11 | 2.6% | 9 | 2.1% | * 81.8% |
| Infrastructure | 12 | 2.8% | 8 | 1.9% | 66.7% |
| Library | 46 | 10.9% | 15 | 3.6% | ° 32.6% |
| National Parks | 13 | 3.1% | 12 | 2.8% | * 92.3% |
| Operations Maintenance | 7 | 1.7% | 6 | 1.4% | * 85.7% |
| Operations Management | 11 | 2.6% | 7 | 1.7% | 63.6% |
| Parks Bushland Services | 69 | 16.4% | 68 | 16.1% | * 98.6% |
| People & Organisational | 1 | 0.2% | 0 | 0.0% | ° 0.0% |
| Roads Management | 65 | 15.4% | 64 | 15.2% | * 98.5% |
| Strategy & Planning | 11 | 2.6% | 7 | 1.7% | 63.6% |
| Treasury and Risk | 2 | 0.5% | 2 | 0.5% | * 100.0% |
| Water Services | 18 | 4.3% | 17 | 4.0% | * 94.4% |
| Other | 2 | 0.5% | 0 | 0.0% | ° 0.0% |
| **Total** | n=422 | 100.0% | Male= 283 | Male= 67.1% | |

* Indicates Male >67%; ° Indicates Female >67%

**Test Activities**

The test exercises were selected based on having significant elements of lumbo-pelvic-hip function and being recognized for reducing symptomology or risk of LBP. The five selected exercises were chosen to represent a balanced variation of functions required for normal daily activities[35]. Three exercises previously investigated, 'repeated sit-ups', 'repeated squats', and 'extension in lying' (EIL)[38], showed a positive correlation with LBP and were, consequently, included. The sustained squat and leg extension exercises, respectively require functional movement[36,52] and a predominantly isometric abdominal co-activation[53], which occur or simulate daily, occupational and sports activities[54]. Other exercises were considered but excluded, such as active spine flexion which has shown poor correlation with LBP[55].

All participants were volunteers and performed five functional movement exercises during an educational session with other attendees, supervised by the session leader, a Sports Physiotherapist Certified in McKenzie Manual Diagnostic Therapy. The instructions for exercise justification, instructions, completion and reliability are detailed in Table 2. Intra-observer reliability for screening tests movement instruction is recognised as being moderate-high[56].

**Questionnaire**

During the educational sessions each participant completed a self-report questionnaire: 'How often do you have low back pain?' with three-response options: 'rarely/none', 'sometimes' or 'always/mostly', with the time frame and symptoms interpreted within their life context. This 3-point scale is condensed from the World Health Organisation's five-points: 'never', 'rarely', 'sometimes', 'often', and 'very often'[57]. The three-point response provides an 'intermediate' option, which is critical from psychological and statistical perspectives. Psychologically, three cognitive perspectives facilitate response accuracy by reducing cognitive load[58,59] which improves precision and consistency[60]. Statistically, responses were coded on a 0-1-2 scale[61,62]: 0=rarely/none (No LBP), 1=sometimes (Some LBP), 2=always/mostly (Most LBP).

*Ethics approval* was from the Educational Committee of the Sunshine Coast Council with data collected under James Cook University, H1673 and the University of the Sunshine Coast HREC:S04/48/MC and HREC:08/10.

Statistical analysis was performed using SPSS 23.0 for Windows with significance set at $p<0.05$. Following preliminary data screening to ensure data quality (e.g., no aberrant values), an initial cross-tabulation of LBP (0=none, 1=some, 2=most) and number of exercises was performed to explore whether self-reported LBP was related to the number of exercises completed. A chi-square test evaluated whether the null hypothesis (that the number of exercises completed would be consistent across LBP groups) was tenable or able to be rejected. Standard power calculations on the effect sizes verified that the minimum sample size was exceeded.

**Table 2: Test Activities - Exercise Descriptor and Reliability**

| Test # | Title | Justification for inclusion | Instructions to participants | Successful completion | Test reliability |
|---|---|---|---|---|---|
| 1 | EIL - Extension in Lying - held for 3 seconds | maximal lumbar extension simulates the physical properties of normal spinal movements[36,63] because limited extension[64] is related to LBP[65], clinically impaired spinal control[66], and may inhibit symptom centralization[67,68] | lying face down, hands beneath shoulders, forehead on the floor. Keep your pelvis on the floor, breathe in, press with your arms, raise your chest off the ground, breathing out and increasing the movement until your arms are straight. Hold three seconds | hips/pelvis remain in contact with floor, arms fully extended | ICC=0.95-0.98[69] |
| 2 | SITUP: sit-up from supine performed 10 times | through range, active concentric and eccentric trunk flexion control enables the lumbar spine to dissipate and distribute load and provides a stable area for performing limb and trunk activities[14,36,70,71] | lying face-up on the floor, knees bent, feet flat, arms straight and hands on thighs. Breathe in, slowly sit-up whilst breathing out, move the elbows to touch your knees, rolling forward and up from the floor in a continuous movement, until everything above the buttocks is not touching the ground and your elbows reach your knees. Lower down in a continuous movement without falling or dropping while breathing out. Repeat 10 times | no sudden/rapid inertial motion, trunk not held rigid, feet remain on floor, elbows reach/pass the knees, body doesn't drop down | ICC=0.995[72] |
| 3 | LEGEXT: supine bilateral leg extension performed 10 times | abdominal muscles are used predominantly isometrically to stabilize the body during this exercise[53,73] and relevant to performing many household, occupational and sports activities[54]. The exercise provides co-activation significantly greater than in sit-ups/curl[74] enabling testing of rectus abdominis muscle and the internal and external oblique muscle activation[53] reducing LBP risk when part of a motor control exercise program[75] | lying on back on floor breathing in, head in contact or elevated, knees bent and above the umbilicus, lower back contacts the floor, hands by side or under buttocks. Both legs are straightened, knees straightening until heels touch floor while breathing out. Small amounts of knee flexion are permitted. Return legs to the start position. Repeat 10 times | back and buttocks contact the floor, heels touch the ground, hands remain in start position | [double] leg lower (ICC=0.81-1.00)[54] ICC=0.98[76]; active single leg raise $ICC_{3.3}$=0.95-0.97[77]; abdominal muscle % "time active" is 54-86%[53] |
| 4 | SQUAT: 'toilet squat' barefoot, hands touch feet, held for 3 seconds | squatting is frequently used and associated with many ADLs. It requires optimal lumbar flexion control to ensure normal spinal movements are maintained[36,63], and shear-forces/lateral-movement are minimalized[78]. Squatting is a complex multi-segmental functional movement requiring coordinated biomechanical and neuromuscular components involving the leg and pelvic joints and muscles, respiratory system, with prime-mover muscle activation not significantly affected by common variations in kinetic chain continuity[79]. A semi-rigid spine eliminates planar motion but retains antero-posterior spinal integrity, as spinal flexion generally increases with hip flexion and the associated synergistic lumbar-pelvic action[78,80] which reduces the risk of LBP[81] | standing comfortably, feet shoulder-width apart, arms loosely at your side. Breathe in, slowly squat, as though using a squat-toilet, allow the arms to move forward and hands touch the feet. Hold for 3 seconds | pelvis is lowered, heels/feet flat, fingers touch the feet | Intra-rater Kappa=0.81-1.00 when tested alone[82]; ICC>0.60 within a multi-exercise screen[83] and ICC=0.81[84] |
| 5 | RISEUP: full squat and stand-up, performed 5 times | repeated squatting is functional and readily transfers to multiple ADLs. It requires coordinated prime-mover muscle activation and endurance[79] being the technique of choice for manual handling as net moments, muscle forces and internal spinal loads related to compression and shear force are reduced[85]. Reduces LBP risk and is critical for normal spinal movement[36,63] | complete the squat position described, then rise to full standing with the head rising at the slightly before or at the same time as the buttocks. Repeat 5 times, a short rest is permitted | full squat action as above; on rise trunk rises before buttocks /pelvis, i.e. knee extension before hip | ICC=0.61-0.80, standard error of measurement<3%[86] |

A multinomial logistic regression was performed, exploring whether the number of exercises (EX_SUM) predicted LBP (categorized as 0, 1, 2) to test the null hypothesis that the probability or odds of being classified into LBP groups are not different because of number of exercises performed; and if rejected, to quantify the change in odds or probability of LBP as it relates to number of exercises performed. This test also allowed us to evaluate whether participant gender interacted with EX_SUM, or whether there were non-linear effects present. Regression diagnostics for this analysis (e.g., residuals, influence) were examined to ensure no aberrant cases were inappropriately influencing the analysis[87]. None were identified.

Finally, if the null hypothesis from the prior multinomial logistic regression was rejected, we performed a second multinomial logistic regression on LBP entering each exercise as a predictor (rather than simply the count of number of exercises completed) to examine whether all exercises were uniquely predictive or whether some subset of exercises were more predictive than others. All five exercises were entered simultaneously, allowing for examination of unique effects of each variable controlling for all other variables in the equation. Regression diagnostics were examined and no aberrant cases were identified[87].

**Patient and public involvement**

The research question and outcome measures were developed over a three year period during delivery of a work site back care education program to a regional council in Queensland Australia. This involved both formal and informal work related discussions with attendees and management enabling the program and exercise selection to be progressively modified. This procedure informed program progression, specifically the exercises and their relation to the presence or not of LBP, and ensured the priorities of exercise simplicity for the identification and prevention of LBP. The experience gained by this process refined the program and the selected preferences guiding the statistical relation between the exercises and the presence or not of LBP. The results of each session were disseminated immediately to each participant, and after the initial three years of the program and pilot statistical analysis, the statistical relation was discussed with the council management as part of the program feedback.

## RESULTS

For descriptive purposes, a cross-tabulation of LBP (0=none, 1=Some, 2=Most) and the number of exercises accomplished is presented in Table 3. Most participants reporting no LBP could complete most exercises. For individuals with no LBP, 85.5% could complete at least four exercises. Exercise completion dropped significantly for participants with “Some” LBP. In this group, only 22.9% were able to complete four or more exercises, and for participants with “Most” LBP, only 10.5% were able to complete four or more exercises. Analyzing participants in each category who failed to complete more than one exercise, the pattern is reversed. Only 2.9% of those with no LBP had trouble completing more than one exercise, while 23.7% of those with "some LBP" and 74.3% of those with "most LBP" were unable to complete more than one. A Pearson Chi-square test was performed demonstrating a significant relationship between the variables of 'LBP' and 'number of exercises performed' ($X^2_{(10)}$=300.61, $p$<0 .001).

Table 3: Exercises accomplished as a function of LBP

| Number Exercises completed | | LBP 0 None | LBP 1 Some | LBP 2 Most | Total |
|---|---|---|---|---|---|
| 0 | Count | 1 | 8 | 33 | 42 |
| | % within LBP | 0.6% | 5.6% | 31.4% | 10.0% |
| 1 | Count | 4 | 26 | 45 | 75 |
| | % within LBP | 2.3% | 18.1% | 42.9% | 17.8% |
| 2 | Count | 5 | 32 | 12 | 49 |
| | % within LBP | 2.9% | 22.2% | 11.4% | 11.6% |
| 3 | Count | 15 | 45 | 4 | 64 |
| | % within LBP | 8.7% | 31.3% | 3.8% | 15.2% |
| 4 | Count | 58 | 20 | 6 | 84 |
| | % within LBP | 33.5% | 13.9% | 5.7% | 19.9% |
| 5 | Count | 90 | 13 | 5 | 108 |
| | % within LBP | 52.0% | 9.0% | 4.8% | 25.6% |
| Total | Count | 173 | 144 | 105 | 422 |
| | % within LBP | 100.0% | 100.0% | 100.0% | 100.0% |

A multinomial logistic regression predicting LBP (0, 1, 2, with 0 being the reference group) from the count of exercises that could be completed (EX_SUM, ranging from 0-5), showed a strong effect (initial-2LL=348.246, final-2LL=73.620, $X^2_{(2)}$=274.626, $p$<0.001; Table 4).

Table 4: Model summary entering only count of exercises completed (EX_SUM)

**Model Fitting Information**

| Model | Model Fitting Criteria | Likelihood Ratio Tests | | |
|---|---|---|---|---|
| | -2 Log Likelihood | Chi-Square | df | Sig. |
| Intercept Only | 348.246 | | | |
| Final | 73.620 | 274.626 | 2 | .000 |

As presented in Table 5, as EX_SUM increased incrementally, the odds of reporting some LBP or most LBP reduced substantially: Odds Ratio=0.34 (95%CI=0.27, 0.44) and 0.17 (95%CI=0.12, 0.23), for LBP=1 and 2, respectively. No curvilinear effect was present, nor any gender effect.

Table 5: Parameter estimates

| LBP[a] | | B | Std. Error | Wald | df | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower Bound | Upper Bound |
| 1.0 some | Intercept | 3.622 | .469 | 59.645 | 1 | .000 | | | |
| | EX_SUM | -1.069 | .121 | 77.475 | 1 | .000 | .343 | .271 | .436 |
| 2.0 most | Intercept | 4.628 | .497 | 86.653 | 1 | .000 | | | |
| | EX_SUM | -1.784 | .158 | 127.031 | 1 | .000 | .168 | .123 | .229 |

a. The reference category is: .0 none.

A second multinomial logistic regression with the five exercise variables entered individually, rather than entering the total number accomplished, evaluated whether tests were individually predictive of LBP. As shown in Table 6, overall the effect was similarly strong[87] (initial-2LL=429.93, final-2LL=147.40, $X^2_{(2)}$=282.53, $p$<0.001).

Table 6: Model summary when five exercises entered individually

**Model Fitting Information**

| Model | Model Fitting Criteria | Likelihood Ratio Tests | | |
|---|---|---|---|---|
| | -2 Log Likelihood | Chi-Square | df | Sig. |
| Intercept Only | 429.927 | | | |
| Final | 147.397 | 282.530 | 10 | .000 |

As Table 7 presents, most exercises were individually predictive of LBP (when LBP=1, EIL was not uniquely predictive with all other variables in the equation). All others were statistically significant ($p$<0.002) with odds ratios ranging in magnitude from 0.21 to 0.38. For "Most" LBP (LBP=2), all exercises were significant independent predictors of LBP (all $p$<0.017), with odds ratios ranging from 0.09-0.35.

Sensitivity for the first analysis (percent of participants with LBP correctly classified into LBP category) was 82.3%, and specificity (percent of participants with no LBP classified as such) was 85.6%. The positive predictive value (true positives divided by true and false positives) was 89.1%; and negative predictive value (true negatives divided by true and false negatives) was 77.1%. Sensitivity for the second analysis was 79.5%, and specificity was 87.9%. Positive predictive value was 90.4%, and negative predictive value was 74.9%.

Table 7: Parameter estimates when exercises entered individually

**Parameter Estimates**

| LBP[a] | | B | Std. Error | Wald | df | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|---|---|
| 1.0 | Intercept | 3.320 | .520 | 40.719 | 1 | .000 | | | |
| | EX1_EIL | -.148 | .401 | .136 | 1 | .713 | .863 | .393 | 1.894 |
| | EX2_situp | -1.326 | .284 | 21.827 | 1 | .000 | .266 | .152 | .463 |
| | EX3_legext | -1.101 | .362 | 9.246 | 1 | .002 | .332 | .164 | .676 |
| | EX4_squat | -.959 | .298 | 10.337 | 1 | .001 | .383 | .214 | .688 |
| | EX5_riseup | -1.540 | .413 | 13.929 | 1 | .000 | .214 | .096 | .481 |
| 2.0 | Intercept | 4.415 | .539 | 67.084 | 1 | .000 | | | |
| | EX1_EIL | -1.050 | .440 | 5.698 | 1 | .017 | .350 | .148 | .829 |
| | EX2_situp | -2.010 | .429 | 21.977 | 1 | .000 | .134 | .058 | .310 |
| | EX3_legext | -1.666 | .432 | 14.854 | 1 | .000 | .189 | .081 | .441 |
| | EX4_squat | -1.532 | .414 | 13.672 | 1 | .000 | .216 | .096 | .487 |
| | EX5_riseup | -2.392 | .456 | 27.495 | 1 | .000 | .091 | .037 | .224 |

a. The reference category is: .0.

We also took in to consideration a simple analysis relating the presence or absence of LBP to exercises. This approach, combining two groups of LBP (some, mostly) into one category potentially reduces the goodness of the analysis by combining two different groups into one heterogeneous group. If the two groups were distinct, this would increase error variance and decrease the power and informativeness of the analyses. Ancillary binary logistic regression analyses therefore tested the null hypothesis that the two LBP groups were similar. Results of this analysis, which predicted LBP (i.e., some vs. mostly) showed that EX_SUM was significantly related to this outcome (initial-2LL=339.05, final-2LL=284.96, $X^2_{(1)}$=54.09, $p$<0.001), leading us to reject the null hypothesis and assert that these two groups are significantly distinct.

**DISCUSSION**

Previous research demonstrated a relationship between dynamic physical tests, self-reported LBP and reduced function[38]. However, such research has been neglected in recent decades[29-32] as focus shifted towards physiological and radiological findings[9,10] and biopsychosocial attributes[3,6,7,11]. Grönblad et al.[38] showed three physical exercises (repetitive sit-ups, squats, and EIL) had a positive correlation with LBP. Our current study builds on this research as it expands the number of test exercises. It also shows a higher statistical correlation between physical exercise tests and LBP than found previously. These findings with robust effect sizes, and the 95% confidence intervals[87], demonstrate a substantial relationship. Our results indicate that for each increase in the exercise number accomplished, the odds of having some LBP were about one-third less than that of those participants accomplishing one fewer exercise. The authors feel these research findings are generalizable to settings other than those originally tested due to several factors. The council worker population included 21 distinct occupational categories across manual and sedentary requirements under sustained and moveable loads[48,49]; field work in both outdoor and indoor settings; and included a broad distribution of age groups and both genders which indicate the abilities and capacities of workers that present some of the highest potential risk of LBP[50,51].

This study clearly showed that the presence of LBP is significantly statistically related to the ability to perform the chosen exercise tasks. All exercises were uniquely predictive of LBP (except EIL where LBP=1). The total number of exercises completed was strongly related to LBP. The relevance of a gender effect and potential curvilinear effects was tested as per the accepted recommendation[87] and found to have no effect on the results. Effectively, those able to perform more exercises were substantially less likely to report LBP. Consequently, these exercises have the potential to be a part of the areas of recommended necessary investigation in future research[3,11] in terms of the ability to provide a clinical diagnosis related to the potential or risk that an individual may development LBP, and perhaps even future impairment.

The ability to perform repeated squatting has been demonstrated to be inversely related to LBP as the balance between hip and lumbar spine mobility must be met, i.e. better squatting ability is associated with reduced LBP[47]. These researchers found females more susceptible to LBP if they had lower physical performance capacity, a finding not evident in our study. Further, excess/prolonged squatting has a negative effect through increased LBP[88]. Similarly, EIL is beneficial and facilitates lumbar lordosis maintenance[89]. There is a direct link between a reduced lordosis and LBP[90]. Lordosis maintenance is essential for disc symptomology centralisation for LBP management and preventative exercise strategies[89,91]. The exercise alone was not predictive of LBP.

Back endurance testing is a statistically accurate LBP screening test as poor performance in static back endurance correlates to higher incidence[92,93]. However, EIL is a passive test using the arms as the prime mover. It is possible that individuals with excessive lumbar extensor activation and substitution during this test may confound the results. Further, some studies have indicated that trunk muscle strength measures in isolation are unrelated to LBP symptoms and functional ability .

Exercise therapy is an efficient, cost-effective LBP management strategy[94,95] but there is no evidence to support any single exercise. Coordinated muscle activity around the lumbo-pelvic region is considered vital for mechanical spinal stability[36,96]. Several rehabilitative "stabilization exercise" approaches emphasize retraining functional movement patterns, rather than focusing on specific muscles[35,97,98]. The tests we chose activate and challenge the global muscles of the abdomen and trunk, the "abdominal brace" mechanism[99], and their ability to act and interact in a synergistic and functional manner. We screened functional test performance where the aim was assessing participants' functional status regardless or not of LBP and its known or potential cause. As LBP increases in industrial societies with no clear cause it is important to consider risk factors of physical workload and awkward posture[7] as well as preventative strategies that may play a key role in reducing health care system demands and societal support. The exercise tests we used primarily address abdominal and lumbo-pelvic muscles, and their coordination with lower limb muscle activity and maintenance of balance. This coordination was recently defined as 'integral' in understanding lumbar stability as a complex integrated model[36]. Personal efficiency in physical self-test completion can act as a screening methodology for individuals at risk of LBP. It is, however, important that the method of test performance is considered e.g., there is no relation demonstrated between sit-up performance and LBP when the feet are held[100]. This action preferences hip flexor activity over abdominal participation. Alternative actions that preference abdominal muscles, e.g. partial curl-up, are more highly correlated to LBP[101,102]. Our results provide guidance for future work that may contribute to a comprehensive screening, prevention and management approach to LBP.

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**Study strengths and limitations**

The strengths of this study include the cross-sectional nature, the sample including both genders, diverse age groups and occupations but within one organisation and geographical region. This enabled continuity, and a degree of homogeneity in the otherwise varied sample, that strengthened the statistical findings with respect to general working populations. The sample had adequate power and representation of the constructs under consideration. The findings were statistically substantial in the effect size and the determined relationship between the physical tests and the presence of LBP. Causality, however, cannot be inferred from this study.

Other exercise tests may have similar utility. In choosing the exercise tests, we did not consider exercise dose and specificity for age and gender and these may be confounding factors. However, the statistical findings showed that the exercises chosen were relevant and that neither gender nor age influenced the results.

Other potential limitations were the use of a self-assessed diagnosis as participants were not physically examined and the reported LBP was their interpretation of the area 'above the buttocks to the region of waist'. Additionally, that participant self-reported gender was the only potential moderator or confounding variable included in the data. As noted above, gender itself was not a significant predictor in any analysis ($p$>0.80), and thus not included in analyses reported. We were unable to test for a significant interaction between gender and exercises (e.g., EX_SUM) due to quasi-complete separation in the data. However, a trend appeared where the effects for males were *slightly* stronger. This might represent a direction for future research within larger samples, or simply a sample artefact.

**Future research**

Determining the exercises indicative of LBP is imperative for diagnosis and setting discharge goals, the next step is to determine which intervention regimen/s could improve the ability to harmoniously perform and maintain the exercises in an optimized and scalable manner. This would require a prospective, longitudinal study with symptomatic/non-symptomatic LBP patients. Challenges in assessing efficacy are test-standardisation plus gender variation in repetitions number or degree of movement as males are generally stronger and females more flexible. Further, all measurements at baseline and follow-up must be accurate and sensitive. Consequently, a combination of physical tests and patient-reported outcomes are needed, where many currently preferred tools may not be sufficiently sensitive[27].

Furthermore, this study had limited demographic variables. Consequently, future research may consider moderating factors aside from gender. Perhaps age is a differential consideration. However, the very strong analyses effects observed and that our lack of explicitly modeling these hidden variables would have biased the results toward the null, it is unlikely that unobserved variables are true confounders, but might clarify and increase the sensitivity of some effects if modeled. As an observational study, however, it was not possible to indicate whether gradually training individuals to complete these five exercises could facilitate reductions in LBP. From the authors clinical management protocol it may be speculated that this appears possible.

**CONCLUSION**

In a group of 422, predominantly male, Australian Council workers presenting in a mixed general working population, the ability to complete or not-complete five simple functional exercises showed a significant and meaningful clinical correlation with the presence or absence of LBP. Those able to perform more exercises were significantly less likely to report the presence of LBP, either sometimes or most of the time. Conversely, those unable to perform any or one exercise were more likely to report the presence of LBP most of the time. These findings could not only be useful for diagnostic purposes, but we hypothesised that training pain-free individuals to be able to complete the five exercises on a regular basis could facilitate prevention of LBP in a general working population. Further, that a graded introduction of these or similar exercises as part of a supervised rehabilitation programme, for individuals recovering from an episode of LBP, may facilitate overall recovery and reduce recurrence. A prospective trial to investigate this hypothesis is to be initiated.

## Author Contribution

**Charles Philip Gabel –** provided the concept and design of the study; acquisition of participants and data, assisted data analysis and interpretation, drafting of manuscript and critical revising

**Hamidreza Mokhtarinia** - provided drafting and critical revising of manuscript

**Jonathan Hoffman** - provided drafting and critical revising of manuscript

**Jason Osborne -** provided manuscript design; participants and data analysis and interpretation, drafting of manuscript and critical revising.

**Liisa Laakso -** provided data interpretation, drafting and critical revising of manuscript

**Markus Melloh -** provided concept and design input, assisted data analysis and interpretation, drafting of manuscript and critical revising.

**Competing Interests**

- Nil

**Funding Sources**

- Nil

**Data sharing statement**

- Extra data can be accessed via the Dryad data repository at http://datadryad.org/ with the doi: 10.5061/dryad.9g8q52g

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

| Item | Item No. | Ms Page No. | Recommendation |
|---|---|---|---|
| ✓ **Title and abstract** | 1 | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract |
| | | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found |
| **Introduction** | | | |
| ✓Background/rationale | 2 | 1-2 | Explain the scientific background and rationale for the investigation being reported |
| ✓Objectives | 3 | 2, 6, 7 | State specific objectives, including any pre-specified hypotheses |
| **Methods** | | | |
| ✓Study design | 4 | 4 | Present key elements of study design early in the paper |
| ✓Setting | 5 | 4,7 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection |
| ✓Participants | 6 | 4 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants |
| ✓Variables | 7 | 5-6 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable |
| ✓Data sources/ ✓measurement | 8* | 5-6 | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group |
| ✓Bias | 9 | 4 | Describe any efforts to address potential sources of bias |
| ✓Study size | 10 | 4 & 6 | Explain how the study size was arrived at |
| ✓Quantitative variables | 11 | 6-7 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why |
| ✓Statistical methods | 12 | 6-7-8 | (*a*) Describe all statistical methods, including those used to control for confounding |
| | | | (*b*) Describe any methods used to examine subgroups and interactions |
| | | | (*c*) Explain how missing data were addressed |
| | | | (*d*) If applicable, describe analytical methods taking account of sampling strategy |
| | | | (*e*) Describe any sensitivity analyses |
| **Results** | | | |
| ✓Participants | 13* | 4, 7-8 | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed |
| | | | (b) Give reasons for non-participation at each stage |
| | | | (c) Consider use of a flow diagram |
| ✓Descriptive data | 14* | 5 | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders |
| | | 4 | (b) Indicate number of participants with missing data for each variable of interest |
| ✓Outcome data | 15* | 7 | Report numbers of outcome events or summary measures |
| ✓Main results | 16 | 8-9-10 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included |
| | | | (*b*) Report category boundaries when continuous variables were categorized |
| | | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period |
| ✓Other analyses | 17 | 6-7 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses |

| | | | |
|---|---|---|---|
| **Discussion** | | | |
| ✓Key results | 18 | 10-11 | Summarise key results with reference to study objectives |
| ✓Limitations | 19 | 12-13 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias |
| ✓Interpretation | 20 | 13 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence |
| ✓Generalisability | 21 | 4, 12,13 | Discuss the generalisability (external validity) of the study results |
| **Other information** | | | |
| ✓Funding | 22 | 14 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based |

*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.