

Lumbopelvic movement control in powerlifters with and without low back pain

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ABSTRACT

Objectives: To measure lumbopelvic movement control in powerlifters with and without low back pain (LBP).

Design: Quantitative Cross-sectional.

Participants: Twelve powerlifters with LBP and 28 powerlifters without LBP.

Setting: Powerlifters were recruited in nine different cities and filmed while performing a movement control test battery.

Main outcome measures: Lumbopelvic movement control test battery consisting of seven tests, with a possible score between 0 and 13. The tests were rated by a physical therapist blinded to the group allocation and comparisons of the frequency of current/incorrect tests between groups were calculated.

Results: There was no statistically significant difference in the movement control test battery between the powerlifters with LBP (Median = 7.0, (2–11)) and powerlifters without LBP (Median = 6.0, (1–10)) ($P = 0.59$). There were no statistically significant differences between groups when the individual movement control tests were analyzed separately.

Conclusions: The lack of significant differences between groups indicates that performance in lumbopelvic movement control test might not be associated with LBP in powerlifters. More studies on associations between LBP and movement control and other body functions are needed to guide assessment and treatment of powerlifters with LBP and for investigation of possible risk factors for LBP in powerlifters.

1. Introduction

Powerlifting is a sport that consists of the three barbell exercises squat, bench press and deadlift, where the maximum lifted weight in each of the three exercises are added together forming a total, (IPF). In this maximal strength sport, extremely large forces are exerted on the musculoskeletal system and the load on the spine during barbell squats and deadlifts have been assessed in several studies. The compressive forces in the spine of competitive powerlifters has been shown to reach over 18000 N during the deadlift (Cholewicki, McGill, & Norman, 1991) and in up to 10 times the body weight in the squat (Cappozzo, Felici, Figura, & Gazzani, 1985).

Sub-elite powerlifters in Sweden have been shown to have a point injury prevalence of 70 %, with 22,9 % of injuries in women and 41,7 % of injuries in men being located in the lumbopelvic region (Stromback, Aasa, Gilenstam, & Berglund, 2018). Furthermore, a systematic review reveals low back pain (LBP) to be one of the most prevalent injuries in powerlifters, together with knee- and shoulder injuries (Aasa,

Svartholm, Andersson, & Berglund, 2017). It should however be noted that a recent study on powerlifters with LBP indicate that there may be no difference in the prevalence or severity of pathoanatomical findings, measured with magnetic resonance imaging, in the lumbar spine when compared to age matched powerlifters without LBP (Aasa & Berglund, 2020).

During a week of training, powerlifters expose themselves to extreme loads on multiple occasions and it could be hypothesized that some components of their training could modulate the risk for the development of LBP in powerlifters. Currently there are no evidence supporting specific risk factors for injuries in powerlifting, however, lumbopelvic movement control is frequently emphasized as a potential risk factor for injuries in occupational research and in strength and conditioning practices. More specifically, a lifting technique with excessive spinal flexion in squats and deadlifts have been propagated as a risk factor for injuries, and in contrast, maintaining a stable neutral spinal position (i.e. a mid-range position between flexion and extension) is often proposed to be injury preventative (Dudagoitia, García-de-Alcaraz, & Andersen,

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2021; Sjöberg, Aasa, Rosengren, & Berglund, 2020). It should be noted that these hypotheses and recommendations of the importance of specific lifting techniques and maintaining a stable neutral spinal position has yet to be evaluated regarding their potentially injury reductive effects in powerlifters (Aasa et al., 2017). Notably, there are also several studies which have shown that experienced powerlifters and weightlifters do not maintain a stable neutral position of the lumbopelvic area during squat and deadlifts, thus further questioning the aforementioned notion of the importance of spinal motions and injuries (Aasa, Bengtsson, Berglund, & Öhberg, 2019; Bengtsson, Aasa, Öhberg, & Berglund, 2022; Bengtsson, Berglund, Öhberg, & Aasa, 2023).

Currently, clinical examination of lumbopelvic movement control is often assessed through different standardized tests, evaluated by Luomajoki et al., (Luomajoki, Kool, De Bruin, & Airaksinen, 2007, 2008), thought to measure the ability to maintain a neutral position of the lumbopelvic area while moving the extremities. The tests are performed without external load and are supposed to be performed with low effort and multiple repetitions. The rationale of the tests implies that lumbopelvic movement control, and the ability to maintain a neutral position is beneficial in the prevention of LBP and inability could be both a risk factor and associated with persistence of LBP symptoms (S. Sahrmann, Azevedo, & Dillen, 2017). Using this test battery, which assess lumbopelvic movement control in several movement directions as a composite score, it has been shown that individuals with LBP have a significantly inferior performance when assessing compared to healthy individuals (Luomajoki, Kool, De Bruin, & Airaksinen, 2008). So far there are no studies investigating if powerlifters with and without LBP differ in regard to their lumbopelvic movement control, i.e. if LBP in powerlifters is associated with lumbopelvic movement control.

To advance the understanding of LBP in powerlifters it is important to further investigate features which may be associated to the presence of LBP and to evaluate if popular clinical tests also are relevant for powerlifters. Therefore, the aim of this study was to investigate if powerlifters with LBP show signs of an altered movement control in the lumbopelvic region compared to powerlifters without LBP. Specifically, this study aims to investigate two research questions. First, to investigate whether there is a difference between powerlifters with LBP and powerlifters without LBP in a test battery score for movement control of the lumbopelvic region. Second, to determine whether there is a difference between powerlifters with/without LBP in individual movement control tests. It was hypothesized that powerlifters with LBP have an impaired movement control compared to powerlifters without LBP, when comparing the total test battery score and regarding the tests which measure lumbopelvic flexion control.

2. Method

2.1. Design

A cross-sectional study applying a battery of lumbopelvic movement control tests on powerlifters with and without LBP was conducted to answer the research questions. The test battery consisted of seven tests previously evaluated in a non-athletic population with and without LBP by Luomajoki et al. (Luomajoki et al., 2007, 2008). One author, performing the data collection, instructed and filmed the powerlifters performing the tests and another author, thus blinded to whether the powerlifter had LBP or not, made the assessment of their lumbopelvic movement control. The assessment (correct/incorrect performance) was made according to previously described criteria (Luomajoki et al., 2008) when the blinded physiotherapist was watching the films of each powerlifter.

All participants received written and oral information about the study and gave their written consent before inclusion. Participants were informed about their right to end their participation in the study at any time, without stating a reason as to why. The study was carried out in accordance with the declaration of Helsinki and was approved by the

regional ethical review board in Umeå, dnr: 2014-285-31.

2.2. Participants

Recruitment was performed in powerlifting clubs in nine different cities in the north, middle and south of Sweden. Invitations to participate in the study were sent out to each respective powerlifting club by e-mail to their official club representative and through posting in their respective social media groups.

To be included, participants had to be competitive powerlifters with a competition license from the Swedish powerlifting association. Powerlifters with LBP, minimum pain intensity on the numerical pain rating score (NRS) of 1/10, had to report an activity limitation due to their LBP in the bench press, squat and/or deadlift which was measured using a modified version of the Patient-Specific Functional Scale (PSFS) (Stratford, Binkley, Solomon, Gill, & Finch, 1994) where a score lower than 10 on any of the three powerlifting exercises (back squat, bench press or deadlift) was defined as an activity limitation due to their LBP. The definition of LBP used was pain between the costal margin and gluteal fold. Powerlifters with LBP had to have a duration of LBP more than four weeks to be included. Musculoskeletal pain conditions in other parts of the body were allowed for inclusion in both groups.

2.3. Equipment

To film the powerlifters performing the tests during the first data collection, an Apple iPhone model 6S (Apple Inc., USA, CA, Cupertino) filming in 1080 p resolution and a framerate of 60 frames/second was used. When filming the powerlifters in the second data collection, a Samsung NX200 (Samsung, Seoul, South Korea) Full-HD (1920 × 1080 resolution) system camera with 30 frames/second was used. A standard camera tripod was used to stabilize the camera when filming. The table on which the powerlifters performed the tests varied but was either a massage table or a physiotherapy table adjusted to the same height. During the one leg stance, a transparent ruler was held by an additional standard camera tripod. Measures of distances between camera and table including height of camera tripod were standardized (Fig. 1) to optimize reproduction of the camera setting between the different locations during data collection.

2.4. Lumbopelvic movement control test battery

Seven tests were used to test for lumbopelvic movement control, as described by Luomajoki et al. (Luomajoki et al., 2008). All tests were performed with three repetitions and to be considered as an incorrect performance, all three repetition had to be incorrect. If powerlifters failed to regain the correct start position in any of the repetitions, that repetition was considered incorrect. The tests are intended to be able to detect impaired flexion, extension, rotation, and lateral shift control. The test battery consists of waiters bow (flexion control), standing posterior pelvic tilt (flexion control), one leg stance (lateral shift control), sitting knee extension (flexion/rotation control), quadruped rocking forward (extension control), quadruped rocking backward (flexion control) and prone knee flexion (extension/rotation control). The one leg stance test was performed on each leg and symmetry between sides were assessed and therefore had a possible score of 0–3. Sitting knee extension and the prone knee flexion were performed uni- and bilaterally, therefore also had a possible score of 0–3 points. The test battery was scored as total number of correct tests scoring between 0 and 13 points. Performance and assessment of the tests are shown in Figs. 2–3, and are also described in depth by Luomajoki et al. (Luomajoki et al., 2008).

The intra-rater reliability for the tests have been shown to have Kappa (k) values between $k = 0.51$ – 0.95 , i.e., moderate to almost perfect intra-rater reliability (Luomajoki et al., 2007). The inter-rater reliability for the tests has been shown to be between $k = 0.43$ – 0.72 , i.e moderate

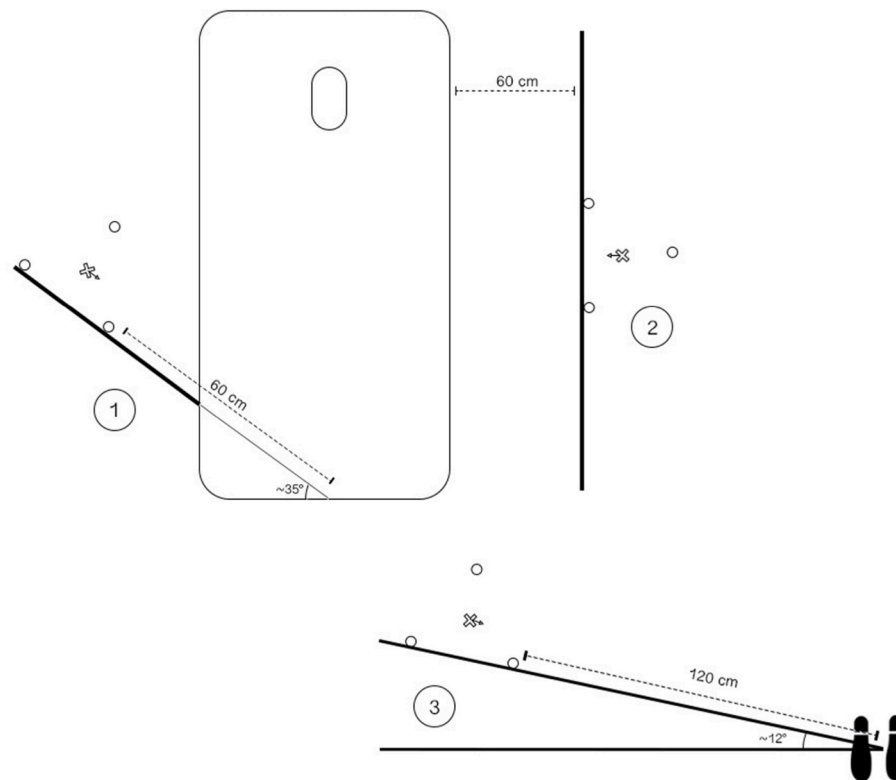


Fig. 1. Standardized camera positions. Schematic picture, seen from above, of camera position including distances (cm) and angles (degrees) between the camera, powerlifter and the table. Three different positions were used for the respective tests: 1) Position for sitting knee extension, 2) Position for rocking backward, rocking forward and prone knee flexion, 3) Position for pelvic tilt and waiters bow standing. Tripod legs are marked with a ○ and the camera including the direction it was facing is marked with a ✕ and arrow (→).

to substantial inter-rater reliability (Landis & Koch, 1977; Luomajoki et al., 2007). With no gold standard for testing lumbopelvic movement control it is not possible to assure that these tests are valid for measuring movement control. However, with the tests previously showing a difference between with and without LBP, it could be considered that the test battery potentially has a degree of discriminative validity (Luomajoki et al., 2008).

2.5. Questionnaires

All powerlifters answered a background questionnaire regarding their current training and competition regime, and current injuries. The questionnaire has been developed, described, and used in previous studies on injuries in powerlifters (Aasa & Berglund, 2020; Stromback et al., 2018). Additionally, as mentioned above, they also answered a modified version of the PSFS for use in the inclusion/exclusion process and to describe the powerlifters activity limitations in the powerlifting exercises. The Roland and Morris Disability Questionnaire (RMDQ) (Roland & Morris, 1983), and Numeric Pain Rating Scale (NRS) (Price, Bush, Long, & Harkins, 1994) was also answered by powerlifters with LBP to further describe their pain and activity limitations. The PSFS, RMDQ and NRS are common and recommended questionnaires for use in studies on LBP and are both considered valid and reliable for quantification of LBP related symptoms and impairments (Chiarotto et al., 2016; Clement et al., 2015; Nazari et al., 2022). Their measurement properties have however not been evaluated on powerlifters.

2.6. Procedure

The data collection started with powerlifters answering the questionnaires. Thereafter they were examined by the test leader, also a physiotherapist, for approximate range of motion (flexion and

extension) in the lumbar spine, in a seated position in order to give the instructor an understanding of where the powerlifter had their lumbar spine neutral position. Before beginning the test, the powerlifters were instructed how to find their neutral position in the lumbar spine in a seated position, which was assessed as being approximately in the middle of the full active range of motion of flexion and extension in the lumbar spine. They were informed of where the test leader considered them to have their lumbar spine neutral position and that this was the position they should assume or maintain when promoted. If they could not assume the correct starting position in the lumbar spine at the beginning of the first repetition, they were instructed how to do so by the test leader.

All powerlifters were filmed performing three repetitions of each movement control test. To be able to assess the performance, all tests were performed in underwear or tights and sports bra. The powerlifters performed all repetitions of each test in one set with no verbal feedback from the test leader. Hence, for the tests that required a neutral starting position in the lower back, the powerlifters had to assume the correct starting position after each repetition on their own. If they failed to regain the correct start position in any of the repetitions, that repetition was considered not correct. Instructions were standardised and given verbally before beginning each test and all powerlifters were shown pictures of correct performance of the tests to assure that lack of understanding did not limit the performance. If the powerlifters did not understand how to perform the test, the instructions were repeated and the test was physically demonstrated by the test leader. Every powerlifter performed the tests in a unique, randomized order to minimize the risk of seeing a learning effect on group level.

All filmed tests were assessed by an experienced physiotherapist, with a master degree in orthopaedic manual therapy, several years of clinical practice and extensive experience with use of the test battery in individuals with LBP. The physiotherapist assessing the tests was




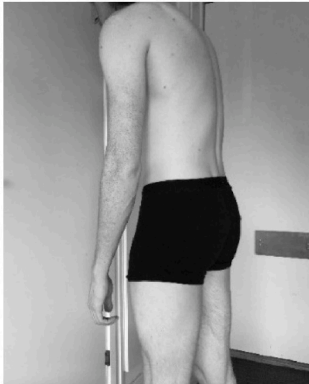
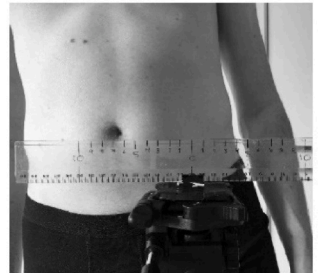
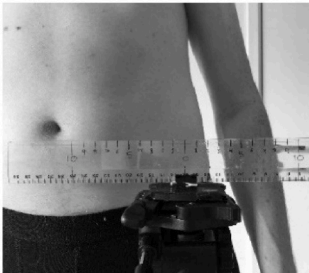


| Test | Correct performance (points) | Correct performance (example) | Incorrect performance (example) |
|------------------------|---|--|---|
| Waiters bow | Forward bend without lumbar flexion, (0-1) |  |  |
| Posterior pelvic tilt | Posterior pelvic tilt without any movement of the thoracic area, (0-1) |  |  |
| One leg stance | Standing on one leg with ≤ 10 cm lateral movement of the belly button and ≤2 cm side difference, (0-3, right, left and side difference) |  |  |
| Sitting knee extension | Sustain neutral position in lower back during knee extension, (0-3, right, left and bilateral) |  |  |

Fig. 2. Assessment of test 1–4, possible score on each of test.

blinded to group allocation, i.e. did not know which powerlifters had LBP. Films were edited so that the powerlifters faces was not visible, ensuring anonymity. The rater was only allowed to watch each film one time and all films were watched in the same order, mimicking how they are commonly performed in a clinical setting, starting with the tests done in standing followed by sitting, quadruped and lastly prone.

2.7. Statistical analysis

The statistical significance (α) was set to 0.05. The data was analyzed using SPSS for Windows, version 28 (IBM Corp., Armonk, N.Y., USA).

The characteristics of the two groups was analyzed differently depending on scale level and distribution. Data on ratio- or interval scale, with normal distribution according to the Shapiro wilks test ($p > 0.05$) and a visually confirmed normal distribution on histogram, was analyzed with an independent t -test. Data on an ordinal scale was analyzed with an independent samples Mann-Whitney U test. Nominal data was analyzed with Fisher's exact test since most expected cell counts were <5 . The difference in the mean total test battery score between powerlifters with LBP and powerlifters without LBP was measured with an independent samples Mann-Whitney U test since it is data on ordinal scale. The difference in number of subjects passing a specific test between

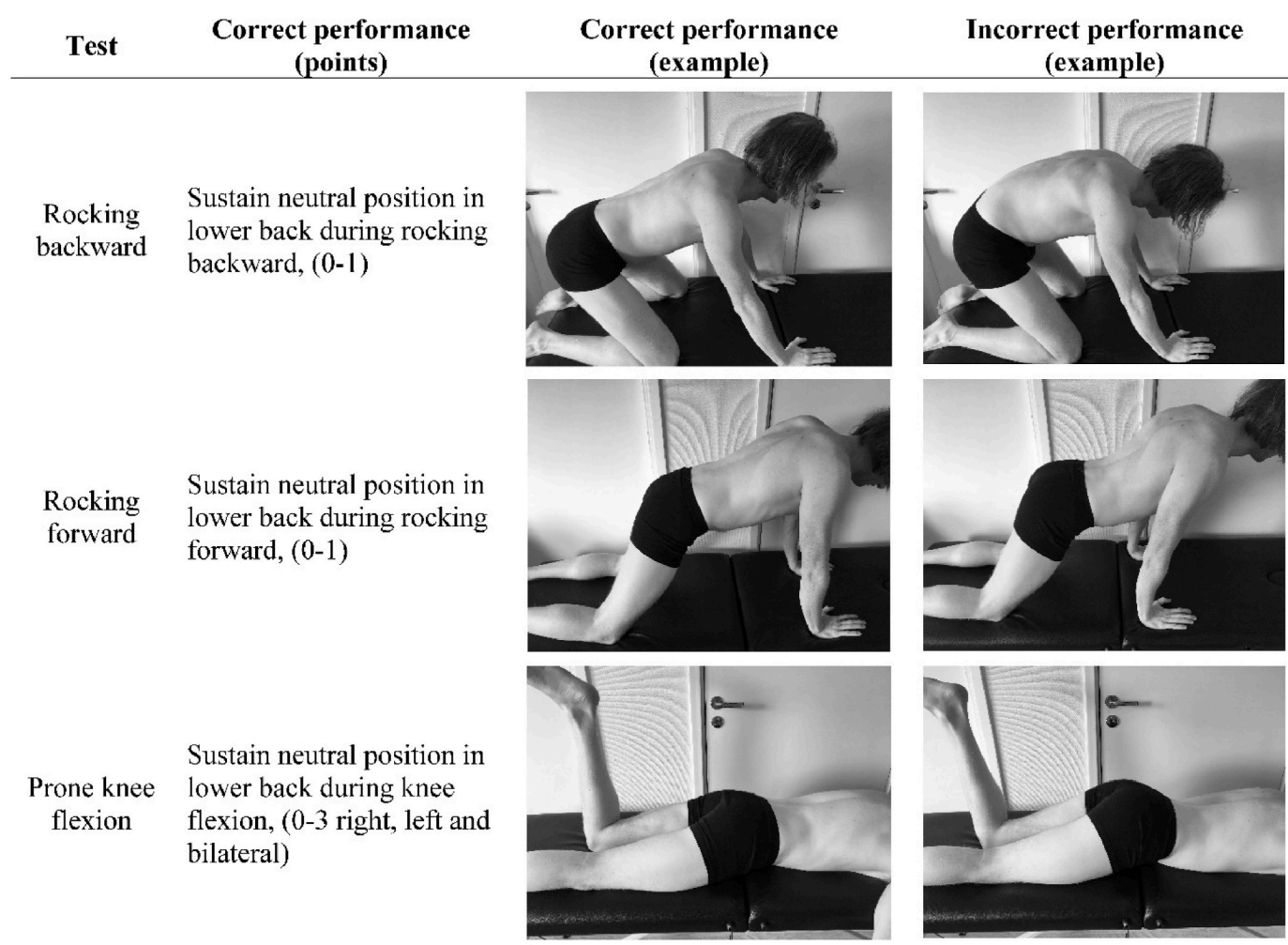


Fig. 3. Assessment of test 5–7, possible score on each of test.

powerlifters with LBP and powerlifters without LBP was measured with a Fisher's exact test, since it is nominal data, and most cells had an expected cell count of <5.

3. Results

Fifty-nine participants were recruited on two different occasions (spring and fall of 2018). After the recruitment process, a total of 19 participants were excluded due to the following reasons: not having a competition license ($n = 9$), not being able to be physically present at the time or place of testing ($n = 8$), not having LBP at the time of testing (but within four weeks of data collection) ($n = 1$), and, having LBP that did not affect lifting, i.e. a score of 30 on the modified PSFS ($n = 1$).

Thus, after exclusion, 40 participants, 12 powerlifters with LBP and 28 powerlifters without LBP remained. The background characteristics of all participants can be seen in Table 1 and training and competition characteristics of the participants are presented in Table 2. The locations of musculoskeletal pain in other body regions than the low back, were hip/groin ($n = 2$), knee ($n = 3$), foot ($n = 1$), shoulder girdle ($n = 4$), elbow ($n = 2$), and wrist ($n = 1$). The group of powerlifters without LBP had musculoskeletal pain in the following body regions, hip/groin/thigh ($n = 6$), knee ($n = 4$), thoracic area ($n = 1$), shoulder girdle ($n = 5$), elbow ($n = 2$), and wrist ($n = 1$).

Background, training, and competition characteristics are presented in Tables 1 and 2, including comparisons between groups for all variables. Both groups were comparable, i.e., no significant differences between groups, in all presented characteristics. No participant reported

Table 1

Background characteristics of participants and group comparisons.

| | Powerlifters with LBP (n = 12) | Powerlifters without LBP (n = 28) | P-value |
|---|--------------------------------|-----------------------------------|-------------------|
| Age years (Mean, SD) | 27.5 (4.8) | 25.2 (4.3) | 0.09 ^a |
| Weight kg (Mean, SD) | 84.8 (15.0) | 84.9 (15.5) | 0.97 ^a |
| Height cm (Mean, SD) | 175.1 (7.2) | 176.1 (8.9) | 0.72 ^a |
| Sex (Male (n, %)) | 8 (67) | 15 (53) | 0.51 ^a |
| Working (n, %) | 7 (64) | 18 (64) | 1.00 ^a |
| Student (n, %) | 4 (36) | 10 (36) | 0.69 ^a |
| Duration of LBP, weeks (Median, IQR) | 92 (99) | – | – |
| Current intensity of LBP, NRS (Median, IQR) | 3 (2.5) | – | – |
| RMDQ 0–24, (Median, IQR), n = 9 | 3 (4.5) | – | – |
| Modified PSFS 0–30 (Median, IQR) | 21.5 (3.8) | – | – |
| Other pain, number of locations (Median, IQR) | 1 (2.5) | 1.8 (1.0) | 0.1 ^a |
| Intensity of other pain, NRS (Median, IQR) | 3 (4.5) | 3 (2) (n = 15) | 0.91 ^a |

^a = Independent T-test; [†] = Mann Whitney U test; ^{***} = Fishers exact test; SD = standard deviation; LBP = low back pain; NRS = Numerical pain rating scale; IQR = Interquartile range; RMDQ = Roland Morris disability questionnaire; PSFS = patient specific functional scale.

Table 2
Training and competition characteristics of participants and group comparisons, (Mean, (SD)).

| | Powerlifters with LBP (n = 12) | Powerlifters without LBP (n = 28) | P- value |
|----------------------------------|-----------------------------------|--------------------------------------|-------------------|
| Gym training (years) | 8.6 (5.1) | 8.1 (4.6) | 0.78 [‡] |
| Competing (years) | 2.8 (2.0) | 3.6 (3.6) | 0.78 [‡] |
| Competitions last 12 mo. (n) | 2.1 (1.1) | 2.4 (1.9) | 0.94 [‡] |
| Powerlifting (workouts/week) | 4.5 (1.0) | 4.6 (0.9) | 0.61 [‡] |
| Powerlifting (hours/ week) | 10.0 (3.1) | 10.7 (3.3) | 0.56 [*] |
| Squat (workouts/ week) | 2.5 (1.1) | 2.8 (1.1) | 0.34 [‡] |
| Squat (hours/week) | 2.5 (0.9) | 2.8 (1.3) | 0.44 [‡] |
| Benchpress (workouts/week) | 3.3 (1.0) | 3.6 (0.9) | 0.34 [‡] |
| Benchpress (hours/ week) | 3.3 (1.3) | 3.5 (1.2) | 0.69 [‡] |
| Deadlift (workouts/ week) | 2.3 (0.9) | 2.4 (1.0) | 0.57 [‡] |
| Deadlift (hours/ week) | 2.3 (0.8) | 2.5 (1.2) | 0.47 [*] |
| Personal best squat (kg) | 159.4 (57.2) | 173.2 (53.7) | 0.47 [*] |
| Personal best benchpress (kg) | 112.5 (28.8) | 121.7 (54.4) | 0.99 [‡] |
| Personal best deadlift (kg) | 201.5 (62.7) | 204.8 (62.4) | 0.88 [*] |

LBP = low back pain; * = Independent T-test; [‡] = Mann Whitney U test. Difference between groups in total movement control test battery score.

pain during any of the movement control tests.
There was no statistically significant difference in total test battery score (0–13) between the powerlifters with LBP (Median, (min-max) 7.0, (2–11)) and the powerlifters without LBP (Median, (min-max) 6.0, (1–10)), as can be seen in Fig. 4 (P = 0.59).
Difference between groups on each movement control test.
There was no statistically significant difference between the powerlifters with LBP and powerlifters without LBP in any of the tests, as can

Table 3
Measurement of central tendency as well as most frequent outcome of each test (mode) in the powerlifters with LBP and powerlifters without LBP. Negative = incorrect test, Positive = correct test.

| | Powerlifters with LBP (n = 12) | Powerlifters without LBP (n = 28) | p- value* |
|------------------------------------|-----------------------------------|--------------------------------------|--------------|
| One leg stance, right | Negative | Negative | 1.00 |
| One leg stance, left | Negative | Negative | – |
| One leg stance, side difference | Negative | Negative | 1.00 |
| Pelvic tilt | Positive | Negative | 0.32 |
| Waiters bow | Positive and negative | Negative | 0.15 |
| Sitting knee extension, right | Positive | Positive | 0.74 |
| Sitting knee extension, left | Negative | Positive | 0.49 |
| Sitting knee extension, bilat. | Positive | Positive | 0.45 |
| Rocking backward | Positive | Positive | 1.00 |
| Rocking forward | Positive | Positive | 1.00 |
| Prone knee bend, right | Positive | Positive | 1.00 |
| Prone knee bend, left | Positive | Positive | 1.00 |
| Prone knee bend, bilat. | Positive | Positive | 0.65 |

LBP = low back pain, * = Fishers exact test.

be seen in Table 3. The percentage of participants that scored positive on each test, in each group, are presented in Fig. 5.

4. Discussion

In this study, a lumbopelvic movement control test battery was performed on competitive powerlifters to investigate if powerlifters with LBP have an altered lumbopelvic movement control. There was no statistically significant difference in how powerlifters with or without LBP performed in the total test battery score or in the individual tests. Thus, from these results powerlifters with LBP does not appear to have an impaired lumbopelvic movement control compared to powerlifters

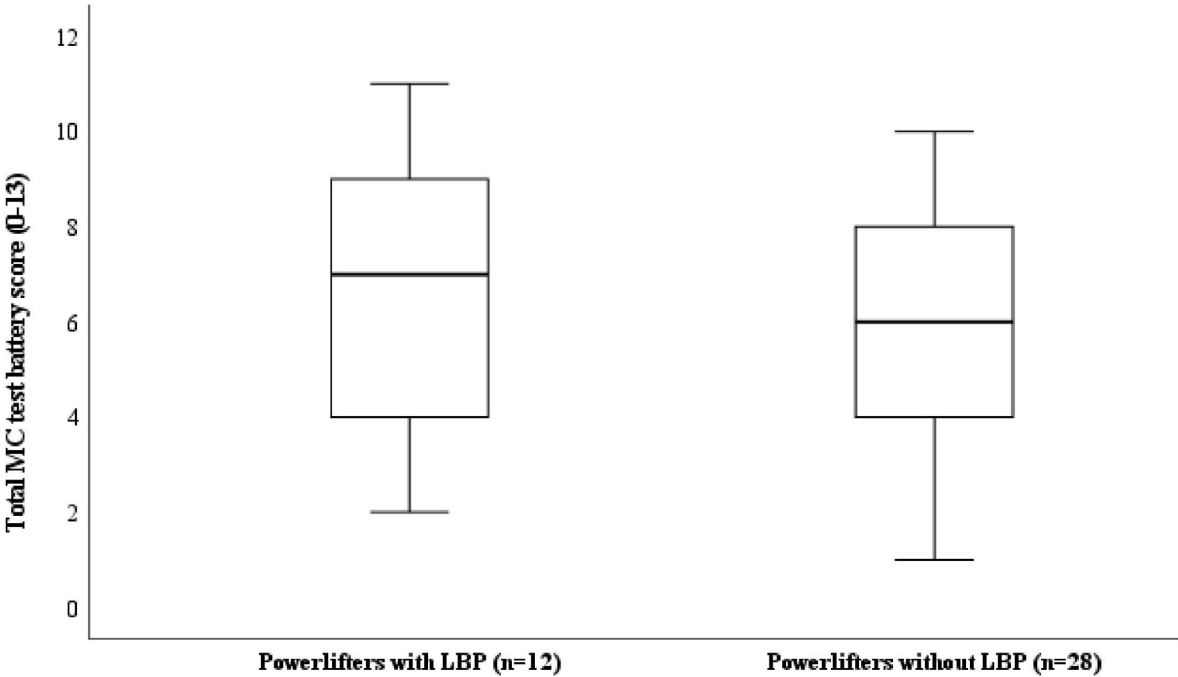


Fig. 4. Boxplot of total movement control (MC) test battery score for the powerlifters with low back pain (LBP) and powerlifters without LBP, respectively. There was no statistical difference between the two groups. The boxplot visualizes the minimum- and maximum values, the interquartile range and the median.

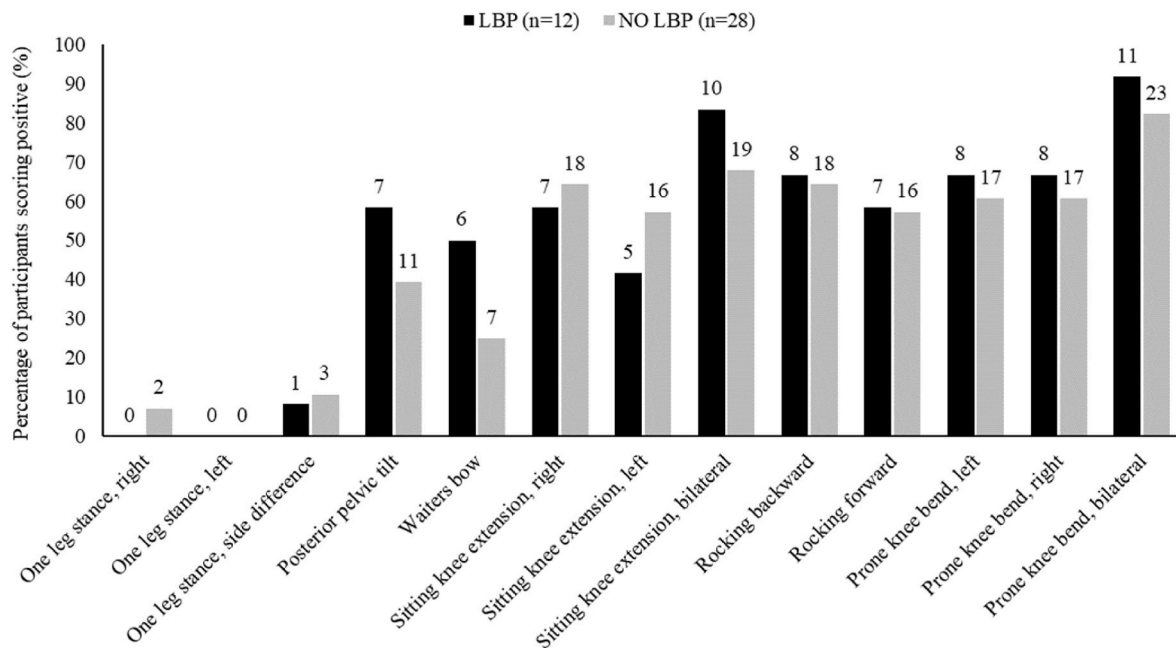


Fig. 5. Percentage of participants scoring positive on each test, in the powerlifters with LBP (LBP, $n = 12$) and powerlifters without LBP (NO LBP, $n = 28$). Absolute number of participants scoring positive over each bar.

without LBP, measured with the Luomajoki test battery (Luomajoki et al., 2008).

One possible explanation of the results is that the movement control impairments which are thought to be identified with these tests might not being associated with injury in a powerlifting population, as opposed to the findings in a general population (Luomajoki et al., 2008). The aetiology of the majority of cases of LBP in a powerlifting population, as in a general population, is unknown (Maher, Underwood, & Buchbinder, 2017). It is however widely believed that faulty technique is a risk factor for LBP in powerlifting (Dudagoitia et al., 2021; Sjöberg et al., 2020). While an altered lumbopelvic movement control, detected with tests such as the ones in this study, could possibly affect the lifting technique in the powerlifting exercises, it should not be assumed. The rationale behind investigating the movement control test battery stems from the extensive clinical use of these tests in patients with LBP and thereby also their use on powerlifters seeking healthcare for their LBP. Therefore, it was important to investigate if these popular clinical tests are relevant for different populations, for example powerlifters, to guide healthcare professionals in their assessment and clinical reasoning process.

However, based on the results, it is likely that more sport specific tests could be able to detect a more relevant lumbopelvic movement control alteration which could discriminate between powerlifters with and without LBP. It is possible that control of the lumbopelvic region during squat and deadlift is important in this population, but that lumbopelvic movement control during non-sport specific tests (such as the tests used in the present study) is not a risk factor. A study by Weyrauch et al. (Weyrauch, Bohall, Sorensen, & Van Dillen, 2015) investigated individuals performing sports with rotational movements such as racket sports. They compared individuals that had LBP and played a rotational sport (LBP + ROT), individuals that did not have LBP but played a rotational sport (NoLBP + ROT) and individuals that did not have LBP and did not play rotation sports (NoLBP-ROT) (Weyrauch et al., 2015). While the LBP + ROT and the NoLBP + ROT had similar results, not unlike in this study, even more interesting was that NoLBP + ROT had a higher degree of lumbopelvic movement impairment compared to NoLBP-ROT. Thus, one could reason that an altered movement that is considered an impairment in a general population might not be considered an impairment in a specific sport.

This notion also brings forth the speculation of a functional adaptation. Sahrmann et al. (Sahrmann et al., 2017) explains the theory behind clinical lumbopelvic movement control tests and the concept of relative stiffness. Relative stiffness refers to the resistance of one muscle to during elongating in relation to other muscles and connective tissue. One example is the stiffness of m. rectus femoris in relation to the anterior abdominal muscles during the prone knee bend test. While a stiff m. rectus femoris is a possible cause of an anterior pelvic tilt during prone knee flexion, stiffness of the m. rectus femoris alone is not a cause, but only in relation to the stiffness of the anterior abdominal muscles. A stiff anterior abdominal musculature will not allow the elongated m. rectus femoris to tilt the pelvis anteriorly. If the m. rectus femoris is stiff in relation to the anterior abdominal musculature however, an anterior pelvic tilt will occur in response to knee flexion. This is suggested to lead to improper movement patterns and subsequently tissue damage and pain. When having higher muscle volume there is also a higher stiffness (Chleboun, Howell, Conatser, & Giese, 1997). With high performing powerlifters having a large muscle mass (Ye et al., 2013) and the effect of resistance exercise on increased tendon stiffness being seen in several studies (Brumitt & Cuddeford, 2015), it is possible that powerlifters have a functional adaptation in form of increased stiffness in certain high demand muscles, thus causing an altered relative stiffness. This has been shown in a previous study by Gadowski et al. (Gadowski, Ratamess, & Cutrufello, 2018) where powerlifters had significantly lesser range of motion in the shoulder region in several clinical tests of range of motion. Therefore, once again, the impairment seen with this test battery does not necessarily have to be a risk factor but might be a normal movement pattern in powerlifters.

4.1. Methodological considerations

There are some methodological considerations that need to be discussed. First, competitive powerlifters with LBP are a highly specific population to investigate at a specific moment in time and was more difficult to recruit than healthy controls. Thus, recruitment of healthy controls was easier than recruiting powerlifters with LBP, causing uneven group sizes decreasing power of the study. Due to this, the risk of a type II error must be considered. With this in mind, there is of course a possibility that there are a difference in lumbopelvic movement control

also in powerlifters, as shown in a non-sporting population (Luomajoki et al., 2008). Because of the achieved sample size, logistic regression analysis, as is usually applied to show a fair representation of the true values, was not possible. Therefore, a simple group comparison was performed to investigate if there was a difference between powerlifters with and without LBP. While the statistical analysis provides answers to the research questions of the present study, it does not provide odds ratio (OR) which possibly is of greater statistical value regarding the effect of the exposure on the outcome.

Second, prioritizing effectiveness of recruitment and inclusion of participants, the two groups were not matched to each other. While commonly being known as a way to control for confounding variables, it has become more evident that matching likely does not (Pearce, 2016). While it does in fact take possible confounder into account, the result of a matched study design is an increase in statistical efficiency (Rose & Laan, 2009) by around 5–15 % (Hennessy, Bilker, Berlin, & Strom, 1999), resulting in a more narrow confidence interval. Weighing the drawback and benefits, considering the difficulty applying this method to this population, a matched study design was considered to cause too many methodological issues compared to the potential benefits.

Third, the movement control tests, and test battery have been described with some variation in previous literature. While Luomajoki et al. (Luomajoki et al., 2008) was first to evaluated the movement control test battery, the tests themselves appear in previous literature with different instructions, performance and assessment criteria (Comerford & Mottram, 2012; Sahrmann, 2002). In the present study, the tests were instructed and performed as described in Luomajoki et al. (Luomajoki et al., 2008). The assessment criteria used in the present study were however formed specific to the present study. With participants being instructed to perform the movements as far as possible without movement of the lower back, and stopping when they feel that they cannot move any further without there occurring movement in the lower back, the tests could be failed in two ways: First, there being a concurrent movement of the lower back in the early stage of the movement or second, the participants not performing the movement far enough. Whether or not these two failures should be considered the same type of lumbopelvic movement control impairment can be discussed. Furthermore, Luomajoki et al. (Luomajoki et al., 2008), used a score of 0–6, with each test getting either a negative or positive score. In this study, a 0–13 score was applied. The 0–13 points system considers a different performance on tests which are performed both uni- and bilateral, thus deemed in this study to serve the purpose of a clinical assessment tool better. Nevertheless, due to the lack of consensus in instructions, performance, and assessment of lumbopelvic movement control tests throughout research, comparability of studies becomes difficult.

While the main limitations of this study have been mentioned, there were also several strengths with the study design. Since the tests were filmed and the rater was blinded to whether the participant had LBP, the risk of confirmation bias was decreased. Filming the participants also allowed for performing the tests in a randomized, unique order to decrease the learning effect between the two group, while at the same time allowing for the rater to assess at the tests in the same order for all participants, mimicking how the tests are commonly used in a clinical setting (Luomajoki et al., 2008). As much as possible, camera position, instructions and assessment criteria were standardized to minimize variability in between participants, ensuring that all participants were assessed on the same basis.

5. Conclusions

This is the first study investigating lumbopelvic movement control in powerlifters with and without LBP. The results imply that performance in non-sport specific lumbopelvic movement control tests are not associated with LBP in powerlifters. It is also possible that powerlifters in general differ from a non-sporting population in key factors, such as

stiffness or range of motion, affecting the performance of lumbopelvic movement control tests. Thus, there might be a need for further studies on more sport specific tests of lumbopelvic movement control for powerlifters, in order to detect an altered lumbopelvic movement control relevant to the powerlifter's injury or pain. Further investigation of other body functions which potentially discriminate powerlifters with/without LBP are warranted to provide information on risk factors and assessment and treatment of LBP in powerlifters. Finally, future studies should also focus on utilizing more accurate methods of movement analysis in order to quantify and compare movement strategies and lumbopelvic movements in powerlifters with/without LBP.

Ethical statement

All participants received written and oral information about the study and gave their written consent before inclusion. Participants were informed about their right to end their participation in the study at any time, without stating a reason as to why. The study was carried out in accordance with the declaration of Helsinki and was approved by the regional ethical review board in Umeå, dnr: 2014-285-31.

Declaration of competing interest

None declared

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