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Original Article

Altered lumbopelvic movement control but not generalized joint hypermobility is associated with increased injury in dancers. A prospective study☆

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Dancers experience significant more low back pain (LBP) than non-dancers and are at increased risk of developing musculoskeletal injuries. Literature concerning the relationship between joint hypermobility and injury in dancers remains controversial. The purpose of this study was therefore to examine whether lumbopelvic movement control and/or generalized joint hypermobility would predict injuries in dancers. Four clinical tests examining the control of lumbopelvic movement during active hip movements were used in combination with joint hypermobility assessment in 32 dancers. Occurrence of musculoskeletal injuries, requiring time away from dancing, was recorded during a 6-month prospective study. Logistic regression analysis was used to predict the probability of developing lower limb and/or lumbar spine injuries. Twenty-six injuries were registered in 32 dancers. Forty-four percent of the dancers were hypermobile. A logistic regression model using two movement control tests, correctly allocated 78% of the dancers. The results suggest that the outcome of two lumbopelvic movement control tests is associated with an increased risk of developing lower extremities or lumbar spine injuries in dancers. Neither generalized joint hypermobility, evaluated with the Beigthon score, nor a history of LBP was predictive of injuries. Further study of these interactions is required.

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1. Introduction

Dancers are at increased risk of developing Low Back Pain (LBP) (McMeeken et al., 2001), as they regularly perform repetitive extensions, high velocity twisting and bending movements. Given the exceptionally high flexibility required for dance, it is not surprising that repetitive movements to extreme positions can contribute to pain. Several studies have revealed increased flexibility and hypermobility in dancers (Klemp et al., 1984; Gannon and Bird, 1999; McCormack et al., 2004). While hypermobile (non-dancing) individuals may be asymptomatic, hypermobility is a predisposing factor of musculoskeletal pain/injury (Kirk et al., 1967; Simmonds and Keer, 2007). It has been suggested recently that evaluating the quality of movement could be more important than measuring the quantity of movement in hypermobile individuals (Simmonds and Keer, 2007). Impaired proprioception has been found in hypermobile individuals (Mallik et al., 1994; Hall et al., 1995). It has been suggested that this could lead to recurrent joint trauma and consequently musculoskeletal pain (Fitzcharles, 2000). Hence, proprioceptive and motor control training have been used in the treatment of hypermobile individuals (Russek, 2000; Ferrell et al., 2004).

The literature concerning the relationship between joint hypermobility and injury in dancers remains controversial (Klemp and Learmonth, 1984; Klemp et al., 1984; McCormack et al., 2004). An extremely high prevalence of injuries has been described in dancers (Garrick and Requa, 1993). Of all professional dancers in Australia, 89% sustain injuries which affect their career and

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approximately 50% of professional dancers have persistent/recurrent injuries (Crookshanks, 1999; Negus et al., 2005). However, it is not clear whether this high prevalence of injuries is related to hypermobility. One hypothesis is that the high prevalence of injuries including LBP is due to repetitive movements in the hypermobile range of movement, which is typical for dancing (McCormack et al., 2004). Another hypothesis is that impaired motor control of the lumbopelvic region leads to compensatory movements of the spine and lower limbs, which results in injuries (Zazulak et al. 2007a, b). However, motor control has not been examined in dancers, despite the high prevalence of LBP in this young population. Therefore, we undertook a study to examine the relationship between motor control, hypermobility and injuries (including LBP) in dancers.

Generalized joint hypermobility can be easily screened according to the Beighton modification of the Carter and Wilkinson criteria. Hypermobility is generally defined as a score higher or equal to 4/9 on the Beighton scale (Beighton et al., 1999). Less consensus exists for defining motor control impairments in clinical settings. A typical feature of impaired motor control is a reduced control of active movements (Luomajoki et al., 2007). An important part of the rehabilitation process, therefore, consists of training of specific lumbopelvic stabilization, independent of any trunk, lower or upper limb movement (Richardson et al., 1992; Sahrmann, 2002). The ability to activate muscles to isometrically hold a position or prevent motion at one joint, while concurrently producing an active movement at another joint, is a movement control test (Mottram and Comerford, 2008). Several authors voice the need for a clinical assessment of active movement control in LBP-patients (Maluf et al., 2000; O'Sullivan, 2005; Luomajoki et al., 2007), but information regarding the clinimetric properties of simple clinical movement control tests is lacking.

1.1. Study aims

The purpose of this study was to examine whether altered lumbopelvic movement control and/or generalized joint hypermobility would predict musculoskeletal injuries to the spine and lower extremities in dancers. In addition, the inter-observer reliability and internal consistency of the four clinical tests examining lumbopelvic movement control were evaluated in patients with chronic LBP and healthy subjects.

2. Methods

2.1. Subjects and research design

All students following a full-time professional Dance Program in Belgium ($n = 32$) were recruited for the prospective part of the study. Twenty-six female (81%) and 6 male (19%) students, aged 20 ± 2 years (range[17–25]) participated in the study. Baseline assessment included medical history, examination of lumbopelvic movement control and generalized joint hypermobility. Movement control and hypermobility were examined by an assessor blinded to the medical history of the dancer.

The occurrence of injuries of the dancers was recorded every 2 weeks during a 6-month follow-up period, by assessors blinded to the outcome of the baseline assessment. Injuries were defined as any musculoskeletal condition requiring time away from dancing and were registered using a standardized questionnaire and subjective evaluation.

Prior to participation, all subjects received verbal and written information addressing the nature of the study. Demographic information was recorded by the time of testing. The Human Research Ethics Committee of the University Hospital approved the study and written informed consent was obtained from all participants prior to testing.

2.2. Instrumentation

The Pressure Biofeedback (PBU) has been developed to monitor lumbopelvic movement by recording pressure changes during assessment and exercise (Richardson et al., 1992; Jull et al., 1993). Calibration studies demonstrated that pressure recordings resulted from lumbopelvic movement and positional changes and were independent of the individual body weight (Jull et al., 1993). The PBU is sensitive to small movements associated with deep muscle recruitment within 2 mm Hg of pressure change (Falla et al., 2003). A high level of agreement has been found between the results of the prone abdominal drawing-in test, recorded with the PBU and converted to categories and a delayed contraction of transversus abdominis (Hodges et al., 1996). Furthermore, a blinded observer was able to detect the presence or absence of LBP with the use of the prone abdominal drawing-in test, recorded with the PBU (Cairns et al., 2000).

The visual analogue scale (VAS – 100 mm) was used for the assessment of lumbar pain severity. The VAS score is believed to be reliable, valid, and sensitive to change (Jensen et al., 1986; Ogon et al., 1996).

An international long-arms goniometer[1] was used for the evaluation of elbow and knee joint angles (assessment of generalized joint hypermobility).

A standardized questionnaire was used to collect demographic information at baseline, and an injury registration form was used for the assessment of musculoskeletal symptoms and injuries (Cumps et al., 2007). With this injury registration form information about the symptoms and injury occurrence, the time loss and the medical diagnosis were gathered. This injury registration form has already been used in prospective epidemiology research in sportsmen (Cumps et al., 2007).

2.3. Procedure

Generalized joint hypermobility was assessed according to the description provided by Beighton et al. (1999). The clinimetric properties of the Beighton score have been summarized elsewhere (Nijs, 2005). Three subgroups were defined based on the individual Beighton scores: tight (0–3); hypermobile (4–6); extremely hypermobile (7–9) (Stewart and Burden, 2004).

Lumbopelvic movement control was assessed by evaluating the subjects' ability to control movement of lumbopelvic region while performing simple movements in the hips. Four commonly used clinical tests, i.e. the Active Straight Leg Raising (ASLR), Bent Knee Fall Out (BKFO), Knee Lift Abdominal Test (KLAT) and Standing Bow (SB), were used in the present study for the evaluation of lumbopelvic movement control. ASLR, BKFO and KLAT were performed in supine position and monitored with a PBU. The pressure was inflated to 40 mm Hg (baseline pressure) (Richardson et al., 1992). Prior to the test, the subjects performed two inspirations and expirations. The pressure was then readjusted to 40 mm Hg. The participants were instructed to maintain neutral spine position (i.e. preventing spinal movement) during lower extremity movement. The other leg was extended (ASLR, BKFO) or flexed (KLAT), and rested on the table. A pre-testing trial was organized to familiarize the subjects with the PBU and the clinical tests. Maximal pressure deviation from baseline was recorded during each test and these scores were used for further analyses.

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The aim of the test was to have as little deviation from the baseline pressure as possible. Although it is unnatural to keep the spine rigid during movements, previous research demonstrated that healthy subjects with good trunk stabilization are able to maintain neutral spine position while moving the legs (Jull et al., 1993). Jull et al. (1993) developed a method to measure active control of the trunk by loading in the sagittal plane (unilateral leg load). These unilateral leg movements were considered to be low load. In this study, subjects who automatically pre-activated the transversus abdominis and internal oblique controlled the lumbopelvic position during the application of low load, with low pressure changes as result. Jull et al. (1993) therefore suggested that 'excessive' pressure changes during low loaded exercise reflect an inability to maintain isometric contraction of the abdominal muscles, resulting in uncontrolled movement of the lumbar spine. They did, however, not defined these 'excessive' pressure changes.

ASLR was performed in the supine position, according to the procedure as described in Roussel et al. (2007). During the first phase, the participant lifted the extended leg 20 cm above the table (phase 1). Next, the subject held this position for 20 s (phase 2). The PBU was placed horizontally under the spine of the participant, with the lower edge at the level of the posterior superior iliac spines.

For BKFO (see Fig. 1), the subject was positioned supine in partial crook lying position, as described by Comerford and Mottram (2001). The participant then slowly lowered out the bent leg to approximately 45° of abduction/lateral rotation, while keeping the foot supported beside the straight leg, and then returned to the starting position. It has been suggested that abdominal muscles should activate to stabilize the trunk in coordination with the adductors, which eccentrically lower the leg (Comerford and Mottram, 2001). For BKFO, the PBU was positioned vertically under the lumbar spine on the side of the bent leg, with the lower edge 2 cm caudal of the posterior superior iliac spine. A folded towel was placed under the lumbar spine on the side of the extended leg, so as to keep both sides of the lumbar spine at the same height. Pressure changes were recorded during the outward movement only. In case of left rotation, the pressure of the left PBU increases (i.e. rotation towards that side), while the pressure in the right PBU decreases.

KLAT (see Fig. 2) was based on the abdominal exercises described by Sahrmann (2002) and on the isometric stability test performed by Wohlfahrt et al. (1993). The subjects were positioned in crook lying and were asked to lift one foot off the table to 90° of hip flexion with knee flexion, keeping the lumbar spine stable. Differences in temporal patterns of activation between healthy subjects and LBP-patients have been found during this test, indicating a lack of synergistic co-activitation in LBP-patients (Hubley-Kozey and Vezina, 2002). The PBU was placed horizontally under the spine of the participant, with the lower edge at the level of the posterior superior iliac spines. An increase in pressure during the test indicates lumbar flexion or posterior pelvic tilt, while a pressure decrease suggests lumbar extension or anterior pelvic tilt (Richardson et al., 1992).

Fig. 1. Bent Knee Fall Out. The subject is instructed to lower out the bent leg to approximately 45° of abduction/lateral rotation, while keeping the foot supported beside the straight leg, and then to return to the starting position.

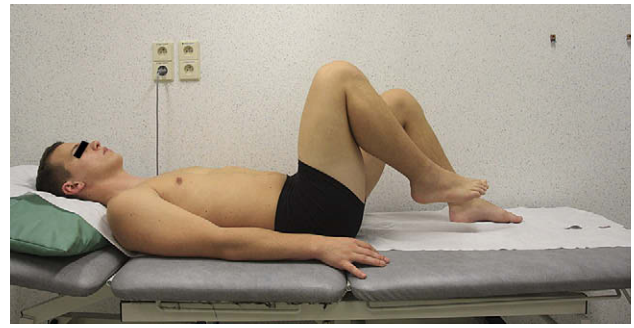

Fig. 2. Knee Lift Abdominal Test. The subject is instructed to lift one foot off the table to 90° of hip flexion with knee flexion, keeping the lumbar spine stable.

The SB (see Fig. 3) was executed in standing. First, the examiner positioned the spine in a neutral position, i.e. in the midrange between anterior and posterior pelvic tilt. Next, the participant was instructed to keep the spine in a neutral position while moving forwards in the hips till approximately 50°, without flexing/extending the lumbar spine (Luomajoki et al., 2007). The test was scored with visual inspection and palpation (Comerford et al., 2007). Bending forwards from the hips, keeping the spine in neutral position, certainly does not reflect normal movement and therefore challenges lumbopelvic movement control. For a correct performance of SB (score 0), stabilizing muscles of the trunk activate isometrically to keep the spine in neutral position, while the hip and back muscles contract to bend forwards. A lack of ability to actively control or prevent a compensatory movement when required or instructed to do so is considered to be uncontrolled motion (Mottram and Comerford, 2008). As the subjects were unfamiliar with the test, only clear movement dysfunction (flexion or extension during the test) was rated as a loss of lumbopelvic stability (score 1). If the movement control improved by instruction and correction, it was considered that it did not infer a relevant movement dysfunction (Luomajoki et al., 2007), and a score of 0 was given.

2.4. Analysis of the inter-observer reliability and internal consistency

The inter-observer reliability and internal consistency of these 4 lumbopelvic movement control tests were assessed prior to the study. Two assessors examined the ASLR, BKFO, KLAT and SB in 27 patients with chronic (>3 months) non-specific LBP, diagnosed by a physician, and 25 healthy subjects. The first test session was followed by 10-min rest. The subject was then examined by the second investigator. In three 1-h training sessions prior to data collection, the examiners were trained in performing the tests under supervision of two manual therapists.

Intra Class Correlation-Coefficients (based on the pressure recordings during ASLR, BKFO and KLAT) and κ-coefficients (for SB) were used for the reliability analysis. Moderate to high inter-observer reliability was found for ASLR and BKFO with ICC-coefficients varying between 0.61 and 0.91, except for the left second phase of the ASLR in healthy people (ICC = 0.41). High reliability was found for KLAT (ICC > 0.85). The weighted kappa for the inter-observer reliability of the SB in healthy subjects and in patients was

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Fig. 3. Standing Bow. Reprinted with kind permission of © PhysioTools Ltd.[2]

0.80 and 0.78 respectively ($p < 0.001$). The Cronbach α-coefficient for internal consistency for ASLR, BKFO and KLAT was 0.83 for the patients and 0.65 for the healthy subjects ($p < 0.01$).

2.5. Statistical analysis

All data were analyzed using SPSS 12.0© for Windows.[3] A 1-sample Kolmogorov–Smirnov goodness-of-fit test was used to examine whether the variables were normally distributed. All variables were found to be normally distributed ($p > 0.05$). A step-wise conditional logistic regression analysis, an independent t-test and Spearman correlation-coefficients were used, in addition to descriptive statistics. The development of injuries to the lower limbs and lumbar spine during the prospective part of the study was considered as the dependant variable. The significance level was set at 0.05, except for the correlation analysis, where the significance level was set at 0.01 to help protect against potential type-I errors. A power analysis (using SigmaStat[4]) determined that 25 subjects per group were necessary for the reliability analysis to establish statistical significance at a power of 0.90. This power analysis was based on a presumed correlation of 0.60 between the observers.

3. Results

At baseline assessment, 63% of the dancers reported a history of LBP. Twenty-six injuries were registered in 32 dancers during the 6-months prospective study (see Table 1). Table 2 display the results of the movement control tests ASLR, BKFO and KLAT. Four dancers (13%) could not maintain the neutral position of the lumbar spine during SB.

Table 1
Localization of the injuries in dancers.

	Number of injuries ($n = 26$)
Hip	3 (12%)
Knee	4 (15%)
Muscles lower legs	4 (15%)
Ankle & Foot	8 (31%)
Spine	5 (19%)
Upper extremities	2 (8%)

The mean Beighton score for generalized joint hypermobility was 4.0 ± 2.3 (range:[0–9]). Fourteen of the 32 dancers (44%) scored above the 4/9 criterion for hypermobility (see Fig. 4). Eight of these 14 dancers (25%) presented a score ranging from 4 to 6, and six dancers (19%) were excessively hypermobile (score 7–9 according to the classification of Stewart and Burden (2004)).

The movement control test battery was used in combination with the assessment of generalized joint hypermobility in order to analyze the predictive value of these tests, i.e. the prediction of the probability of developing injuries to the lower extremities or the lumbar spine. The dancers were divided into 2 groups based on the results of the prospective study (i.e. developing musculoskeletal injuries during the 6-months follow-up or not). A logistic regression model using KLAT and SB, correctly allocated 78% of the dancers in one of the 2 groups ($p < 0.05$). Data of the regression analysis is presented in Table 3.

Generalized joint hypermobility did not correlate with the motor control tests (rho ranging between −0.03 and 0.33), and was neither associated with the development of musculoskeletal injuries (rho = −0.03, $p = 0.89$), nor with a history of LBP (rho = −0.03, $p = 0.89$). Dancers with a history of LBP did not develop more injuries than dancers without a history of LBP ($p = 0.93$, $t = -0.90$).

4. Discussion

Results regarding the relationship between joint hypermobility and injury in dancers remain controversial (Klemp and Learmonth, 1984; McCormack et al., 2004). While hypermobile individuals may be asymptomatic, hypermobility may be a predisposing factor of musculoskeletal pain/injury (Kirk et al., 1967; Simmonds and Keer, 2007). However, it has been suggested recently that an evaluation of the quality of movement could be more important than measuring the quantity of movement in hypermobile individuals (Simmonds and Keer, 2007). For this reason, both movement control and generalized joint hypermobility were assessed in professional dancers in the present study. Our results show that two movement control tests are able to predict injuries in dancers. In contrast, generalized joint hypermobility is not associated with a higher prevalence of musculoskeletal injuries.

Table 2
Mean (X) and Standard Deviations (SD) are given for Active Straight Leg Raise (ASLR), Bent Knee Fall Out (BKFO) and Knee Lift Abdominal Test (KLAT) in 32 dancers.

	Left side	Left side	Right side	Right side
	Mean (SD)	Range	Mean (SD)	Range
ASLR Phase 1 (mm Hg)	45.0 (3.93)	[34–52]	43.9 (4.72)	[30–52]
ASLR Phase 2 (mm Hg)	45.9 (3.63)	[38–52]	45.1 (3.56)	[38–54]
BKFO (mm Hg)	46.1 (2.73)	[40–54]	45.3 (2.31)	[40–50]
KLAT (mm Hg)	48.0 (4.05)	[44–60]	47.2 (2.68)	[44–54]

[2] PhysioTools UK, 8 Culverwell Cottages, Pilton BA4 4DG, United Kingdom.
[3] SPSS Inc. Headquarters, 233s. Wacker Drive, 11th floor, Chicago, Illinois 60606, USA.
[4] Systat Software, Inc. 1735, Technology Drive, Ste 430, San Jose, CA 95110, USA.

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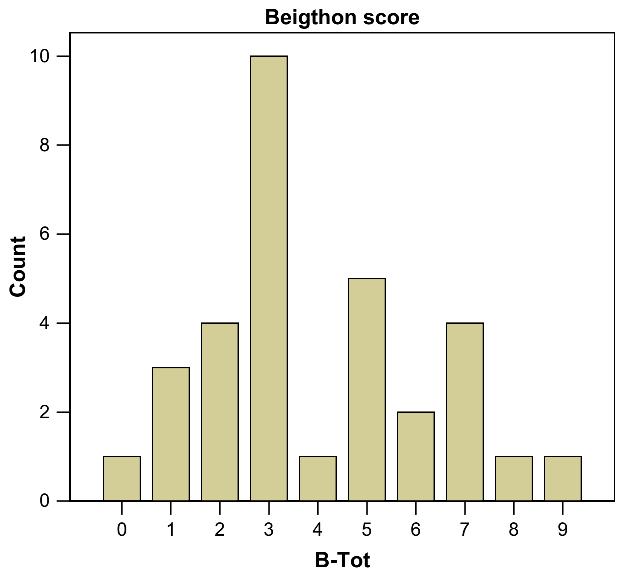

Fig. 4. : Spread of hypermobility ratings (Beigthon Total Score) in 32 dancers. B-Tot = Beigthon Total Score (0–9); Count = number of dancers with a particular Beigthon score.

Sixty-three percent of the dancers reported a history of low back pain. This is in line with the study by McMeeken et al. (2001), who found an incidence rate of 49% in female and 59% in male dancers. Twenty-six injuries occurred during the 6-months follow-up period: seventy-three percent to the lower extremities and nearly 20% to the spine. These results are in accordance with the literature about dance injuries (Garrick and Requa, 1993; Byhring and Bo, 2002). Dancers are therefore at increased risk for developing musculoskeletal complaints to the spine and lower extremities.

The ability to stabilize the lumbopelvic region during limb movement has been studied in elite gymnasts (Mulhearn and George, 1999), but not in dancers. Mulhearn and George (1999) found an association between impaired postural muscle endurance, a lordotic posture and LBP. As they reported a cross-sectional study, no conclusions could be drawn about the causal relationship.

In the present study, four simple tests were used to evaluate lumbopelvic movement control in a clinical setting. To our knowledge, ASLR, BKFO and KLAT have not been evaluated before with the PBU. Therefore the reliability and internal consistency were evaluated in LBP-patients and healthy subjects prior to the prospective study in dancers. Moderate to high ICC-values have been found for ASLR and BKFO, high ICC-coefficients were recorded for KLAT, and excellent inter-observer reliability was found for SB. The results of the reliability study therefore suggest that these tests can be used with acceptable reliability in clinical practice. The Cronbach α-coefficient for internal consistency for ASLR, BKFO and KLAT was high, suggesting that all these tests assess the same underlying dimension, i.e. impaired movement control.

Interestingly, different compensatory strategies were observed during testing. While a posterior pelvic tilt was observed during the movement control tests in some subjects, anterior pelvic tilt was also seen in others. Posterior pelvic tilt leads to a pressure increase, whereas anterior pelvic tilt decreases the pressure (Richardson et al., 1992). Unfortunately, only the maximal pressure excursion was registered and not the variation in pressure within one test performance. Anterior pelvic tilt and variation in pressure were indeed observed during clinical evaluation in dancers, but were not registered in the present study. A (hyper)lordotic posture is common in dancers and gymnasts and has been associated with an increased injury risk in female gymnasts (Steele and White, 1986). The increase in hyperlordosis during dancing could be the result of a deficit in abdominal control to counteract anterior pelvic tilt during hip extension. Further study is nevertheless required to verify this assumption.

Table 3
Logistic Regression analysis in 32 dancers. KLAT = Knee Lift Abdominal Test, Exp(B) = Exponent of B-coefficient, CI = Confidence Interval.

	B-coefficient	Wald *Z* score	Exp(B)	*p*-Value	95%CI for Exp(B)	
					Lower	Upper
KLAT right	−0.531	5.920	0.588	0.015	0.383	0.902
Standing bow	2.173	4.740	8.782	0.029	1.242	62.086

The hypermobility scores found in the dancers are comparable to other studies performed in dancers (Gannon and Bird, 1999). However, generalized joint hypermobility did not correlate with the motor control tests and was not associated with a history of LBP. Moreover, neither joint hypermobility or a history of low back pain, but instead the outcome of two lumbopelvic movement control tests at baseline measurement were able to predict the probability of developing injuries to the lower extremities or lumbar spine in the present study. These results can be explained by an optimal neuromuscular control which compensates a decrease of the passive stability system, due to joint hypermobility (Panjabi, 1992; Reeves et al., 2007). Altered lumbopelvic movement control may force the dancer to compensate in the lower limbs, leading to musculoskeletal injuries. A research of the existing literature revealed only one study examining the predictive value of a lumbopelvic motor control evaluation. Zazulak et al. (2007a, b) demonstrated that impaired core stability predicted the risk of knee injuries with high sensitivity and moderate specificity in female athletes. However, injuries to the lumbar spine, hips or ankles were not examined in their study. There is no other data available regarding the predictive value of lumbopelvic motor control tests. These preliminary results are exciting, and could have an important clinical consequence. Indeed, it is possible to improve lumbopelvic motor control during physiotherapy sessions. Our data suggest that especially dancers with a positive SB and low pressure increase during KLAT are at risk to develop injuries to the lower limbs. An uncontrolled anterior pelvic tilt may account for this negative relationship in the regression analysis between the pressure results during KLAT and the increased risk for developing injuries. As the pelvic movement was not directly measured in the present study, further study of these interactions is required.

4.1. Study limitations

Firstly, only the maximal pressure deviation was monitored during the tests. Some subjects first increased the pressure and afterwards decreased the pressure during the movement control tests. These variations in pressure were not registered. Secondly, the physical activity levels were not taken into account. All the students were equally active during the day (as they all have the same dance programme) but the amount of physical activity outside the dance lessons was not evaluated. This could have influenced the predictive analysis. Further research is therefore necessary. Finally, a standardized questionnaire was used for the registration of the injuries in combination with a subjective evaluation. There is no data available regarding the reliability and the validity of this questionnaire.

5. Conclusion

The Knee Lift Abdominal Test and the Standing Bow can be used for the assessment of lumbopelvic movement control. Since these

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tests correctly allocated 78% of the dancers, they may be useful for the identification of dancers at risk for developing musculoskeletal injuries to the lower extremities and lumbar spine. In contrast, neither generalized joint hypermobility, evaluated with the Beigthon score, or a history of LBP is predictive of musculoskeletal injuries. Further research regarding the interaction between altered movement control and the prevention of injuries in dancers is required.

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