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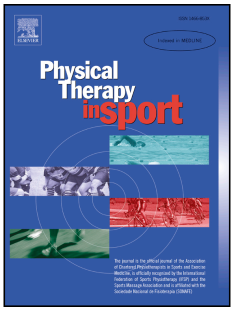

The standing knee lift test is not a useful screening tool for time loss from low back pain in youth basketball and floorball players

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The standing knee lift test is not a useful screening tool for time loss from low back pain in youth basketball and floorball players

ABSTRACT

Objectives: The aim of this study was to investigate the association between pelvic kinematics during the standing knee lift (SKL) test and low back pain (LBP) in youth floorball and basketball players.

Design: A prospective cohort study.

Setting: Finnish elite youth floorball and basketball players.

Participants: Finnish elite youth female and male floorball and basketball players (n=258, mean age 15.7±1.8).

Main Outcome Measures: LBP resulting in time loss from practice and games was recorded over a 12-month period and verified by a study physician. Associations between LBP and sagittal plane pelvic tilt and frontal plane pelvic obliquity during the SKL test as measured at baseline were investigated. Individual training and game hours were recorded, and Cox's proportional hazard models with mixed effects were used for the analysis.

Results: Cox analyses revealed that sagittal plane pelvic tilt and frontal plane pelvic obliquity were not associated with LBP in floorball and basketball players during the follow-up. The hazard ratios for pelvic tilt and pelvic obliquity ranged between 0.93 and 1.08 (95% CIs between 0.91 and 1.07 and 0.83 and 1.29), respectively.

Conclusions: Pelvic movement during the SKL test is not associated with future LBP in youth floorball and basketball players.

Keywords: low back pain, risk factors, prospective study, youth athletes

INTRODUCTION

Low back pain (LBP) is common in youth and presents with a mean lifetime prevalence of 39% (range 8% to 64%) (Calvo-Muñoz, Gómez-Conesa, & Sánchez-Meca, 2013). LBP in youth results in absence from work or school and interference with normal daily activities and recreational physical activities (Coenen et al., 2017). In Finland, nearly half of youth between 11 and 15 years of age participate in organised sports. Studies analysing any association between LBP and physical activity have been inconsistent (Kamper, Yamato, & Williams, 2017), but participation in organised sports might increase the risk for LBP (Franz, Jespersen, Rexen, Leboeuf-Yde, & Wedderkopp, 2016; Hangai et al., 2010). However, prospective studies investigating the risk factors for LBP in youth sports are limited. To effectively decrease the incidence of LBP in youth athletes, the risk factors for LBP should be identified.

LBP prevalence is high in youth floorball (an indoor team sport that resembles floor hockey) and basketball players. In our previous investigation, 44% and 62% of the basketball and floorball players, respectively, reported having had LBP within the previous 12 months (XXX). Both sports include running, sudden turns and stops, as well as other movements performed on single-leg support. In addition, basketball players perform lots of jumping and landing, and floorball includes a lot of positions and movements with a bended trunk because of the relatively short stick used.

The standing knee lift (SKL) test has been used to evaluate hip and pelvic stability (Corkery et al., 2014; DiMattia, Livengood, Uhl, Mattacola, & Malone, 2005;

Elphinston, 2008; Hardcastle & Nade, 1985). Especially in the LBP population, the SKL test and its modifications are often used in clinics to assess if there are impairments in hip and pelvic movement control (i.e., inability to maintain neutral hip and pelvic alignment), and its use has been suggested as a part of functional screening for athletes (Elphinston, 2008). Increased pelvic movement, for example, increased pelvic obliquity or tilt during the SKL test, may be because of impaired movement control. In theory, altered movement control in single-leg tasks may result in increased loading and strain in the lower back area (posterior lumbo-pelvic area) in these floorball and basketball players. Indeed, alignment of the lumbo-pelvic area has been shown to be associated with lumbar loading (Bassani, Casaroli, & Galbusera, 2019; Popovich et al., 2013).

Further investigations analysing any association between LBP and movement patterns in sports is needed (O'Sullivan, Smith, Beales, & Straker, 2017). Hence, the overall aim of the current study was to investigate the association between LBP incidence and pelvic kinematics during the SKL test in youth floorball and basketball players. The study objective was to assess whether increased sagittal or frontal plane pelvic movement during the SKL test is a risk factor for future LBP that would result in time loss from sports participation in youth floorball and basketball players. Our hypothesis was that players with increased pelvic movement during the SKL test would have an increased risk for LBP.

METHODS

This prospective cohort study was approved by the Ethics Committee of **X** Hospital District (ETL-code R10169) and carried out in accordance with the Declaration of Helsinki and the guidelines for good scientific practice. Written informed consent was acquired from the players (and legal guardian if the player was under 18 years old).

Participants and data collection

The present 12-month follow-up study is part of a larger three-year follow-up study (2011 to 2014) investigating lower extremity injuries in youth elite-level floorball and basketball players (**XXXXXX**) (XXXX). Ten female and male basketball and 10 floorball elite-level teams were recruited from the six local sports clubs in Tampere, Finland, for the prospective three-year follow-up study. Three of the 20 teams invited were adult elite-level teams. These adult teams were invited because almost half of the players in the teams were under 21 years old (junior players). Players were excluded if they were older than 21 years old, had an ongoing acute injury affecting the baseline test or did not participate in the test or in the follow-up.

The baseline questionnaire was answered, and the baseline tests (XXX) were performed over one day at the beginning of the study in April 2013. The baseline questionnaire covered basic demographics, sports participation and history of musculoskeletal complaints. The Standardised Nordic questionnaire of musculoskeletal symptoms (the modified version for athletes) was used to assess if the players had a history of LBP complaints (Bahr et al., 2004; Kuorinka et al., 1987). The history of previous LBP was determined based on the following question: ‘How many days have you had LBP during the past 12 months: none (no LBP history), 1–7 days, 8–30 days, >30 days but not daily or daily (history of LBP)?'

Test procedure

The SKL test was used to assess hip and pelvic stability; the test procedure was described in an earlier study by Leppänen et al. (2020). This test is a modified Trendelenburg test (Hardcastle & Nade, 1985) and is often used as a clinical screening test for LBP patients. For the purposes of the current study, a 3D motion analysis was used to assess the performance in the SKL test. The 3D motion analysis comprised eight cameras (Vicon T40, Oxford, UK), 16 lower body markers (Plug-In Gait, Vicon, Oxford, UK) and two force plates (AMTI, Watertown, Massachusetts), where data were recorded synchronously at 300 fps and 1500 Hz.

Prior to the test, 16 reflective markers were placed by one physiotherapist on anatomical landmarks on the lower extremities on both sides (anterior spina iliac superior (ASIS), posterior spina iliac superior (PSIS), lateral thigh, lateral knee joint line, lateral tibia, lateral malleolus and over the shoe on second metatarsal and calcaneus); a static calibration trial was performed.

During the test, the players stood with their feet 20 cm apart (standardised using a 20 cm wide wooden block), one foot on each force plate and arms by their sides. The players were instructed to lift one knee twice to a horizontal level by flexing the hip and knee and holding the position for a few seconds. The stance leg was the side under investigation. The trial was regarded as valid if the player lifted their leg to at least 45 degrees hip flexion and if all markers stayed firmly on the player’s skin throughout the test. Prior to the test, one to three practice trials were allowed. The test started by lifting the dominant leg and then the nondominant leg. Leg dominance was determined by asking about their preferred kicking leg. Trials were excluded as invalid if the hip angle was below 45 degrees, they touched the floor with their foot or the standing foot moved.

The Vicon Nexus Plug-in Gait model was used for the analyses. All the kinetic measurements were performed from foot lift to foot contact, that is, the period when the unfiltered ground reaction force was lower than a threshold of 25 N. The players performed two trials on each leg.

A custom Python (2.7.13) script was used to calculate the pelvic orientations from 3D marker trajectories. For reading and modifying motion capture frames and force plate acquisitions, an open-source Python wrapping of Biomechanical ToolKit platform (BTK 0.3) was used. A standard, open-source Python library for scientific computing (NumPy 1.15.4), data analysis (pandas 0.19.2) and data visualisation (Matplotlib 2.0.0) were utilised for the script. Vertical trajectories of the heel and toe markers were used to detect the knee lift performance from the trial files, and 1000 milliseconds was set as the threshold time for the minimum duration of the valid test trial. Then, the synchronously recorded analogue force plate signals were used to determine the exact timings (motion capture frames) of the foot off and foot strike events. Here, 25N was set as the threshold value. All incorrect or incomplete recordings were removed prior to the analysis because the extracted test trials were checked visually. The plug-in-gait model output specification for pelvic angles was used to determine the peak values for each test trial.

Sagittal and frontal plane pelvic kinematics were investigated, and the following variables were calculated: peak pelvic anterior tilt, peak pelvic posterior tilt (sagittal plane), peak contralateral pelvic hike angle and peak contralateral pelvic drop (frontal plane). The stance leg was the tested leg. The variables are described in Table 1 and Figure 1. For all the investigated risk factors, the mean of two trials was calculated for the right and left legs.

Table 1. The investigated pelvic kinematics

Variables	Description	Interpretation of values
Peak pelvic anterior tilt	Maximal point of the anterior tilt in relation to the global vertical line during the knee lift (mean of two trials).	Positive value = Pelvic tilts anteriorly (PSIS superior to ASIS). Negative value = Pelvis tilts posteriorly (ASIS superior to PSIS).
Peak pelvic posterior tilt	Maximal point of posterior tilt in relation to global vertical line during the knee lift (mean of two trials).	
Pelvic obliquity - Peak contralateral^ drop angle	Angle between the horizontal line and line between left and right ASIS when the contralateral pelvic ASIS is at its lowest point during the knee lift (mean of two trials).	Negative value= contralateral pelvic drop (ASIS drops below horizontal line). Positive value = contrala-

Pelvic obliquity - Peak contralateral^ hike angle	Angle between the horizontal and line between left and right ASIS, when the contralateral pelvic ASIS is at its highest point during the knee lift (mean of two trials).	teral pelvic hike (ASIS stays above horizontal line).

^Contralateral refers to the side of the lifted leg, i.e., contralateral to the tested stance leg.

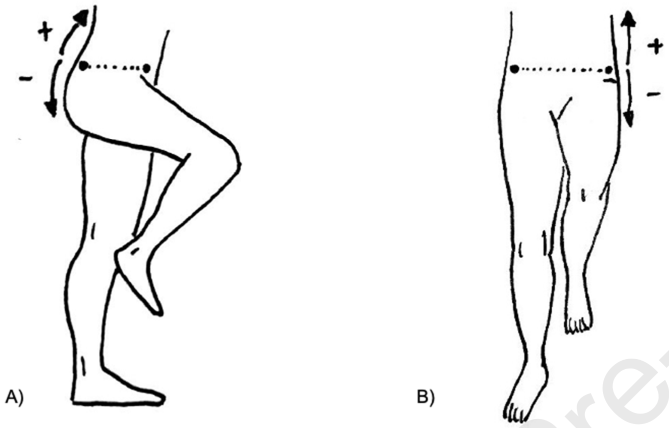

Figure 1. SKL test A) Sagittal plane positive value interpreted as anterior pelvic tilt and negative value as posterior pelvic tilt. B) Frontal plane positive value interpreted as contralateral pelvic hike and negative values as contralateral pelvic drop.

Injury and sport exposure registration

The primary outcome was time loss LBP. Time loss LBP was defined as acute traumatic or gradual nontraumatic onset pain in the lower back area that resulted in time loss from full participation in team practices and games for at least 24 hours. LBP complaints with radiation to the lower legs were not excluded. Direct contact injuries were excluded. A direct contact injury was defined as LBP sustained as a result of direct contact to the lower back (Olsen, Myklebust, Engebretsen, & Bahr, 2004) (e.g., blow to the lower back).

Two study physicians contacted the team coaches weekly to interview the injured players. Information on new complaints was collected using a structured injury questionnaire (Supplementary Table 1), which was based on the recommendations from Fuller et al. (2006). The study did not include systematic clinical examinations or radiological investigations, but a free clinical examination at the UKK Institute was offered to injured players during the study follow-up. During the follow-up, the coaches recorded player attendance in a training session (yes/no), duration of a training session (h), contents of the training session (sports-specific training/condition training) and attendance in each period of a game (yes/no) individually for each player on a player attendance paper form during all team activities. Training and game exposure were defined as suggested by Fuller et al. (2006). If the player did not attend or was injured during the activity, the coach recorded the absence/injury.

Statistical methods

IBM SPSS Statistics (v. 23-24.0) was used to conduct chi-square tests and a t-test (Mann-Whitney tests when appropriate) for descriptive analyses. The results are reported as the mean, standard deviation (SD) and 95% confidence intervals (CIs).

Cox's proportional hazard model with mixed effects was used to study the relationship between the investigated risk factors and LBP incidence. The analyses were performed using R (v 3.1.2; R Foundation for Statistical Computing (R Core Team, 2016)) and the package coxme (Therneau, 2015). Sports club was used as a random effect, and individual game and practice hours from the start of the follow-up until the first event of LBP or the end of the follow-up (if no event) were included in the Cox analyses. Data from all eligible players entering the follow-up were included for the time when they participated.

Univariate analyses were followed by multivariable analyses. Two adjusting variables were used in the multivariable analyses because it has been recommended to have 10 events per included variable in the Cox analyses (Peduzzi, Concato, Feinstein, & Holford, 1995; Peduzzi, Concato, Kemper, Holford, & Feinstein, 1996). First, we included the following factors into one model: age, sex, body mass index (BMI), nicotine use, leg dominance, family history of LBP and history of LBP. Leg dominance was used as two category variables; the categories ‘left’ and ‘right’ were merged into ‘unilateral leg dominance’ and the category ‘don’t know/both’ into ‘bilateral/unknown leg dominance’. Then, the factors were dropped one by one from the model based on their statistical significance (the factors with the largest p-values were dropped). Finally, a history of LBP and leg dominance were entered into the final model because of having the highest statistical significance (smallest p-value). The results are presented as hazard ratios (HRs), 95% CIs and p-values. The player was considered the unit of analysis, and analyses for right and left legs were performed separately.

RESULTS

Nine basketball and nine floorball teams participated in the current study. Thirty-seven players declined and 403 players agreed to participate in the three-year open cohort study. Seventy-nine percent (n=319) of the players agreed to participate during the third study year (2013–2014). Forty-nine players did not have complete SKL test data, eight players did not participate in the follow-up, and four players reported an ongoing acute unilateral injury at the time of testing and were excluded from the analyses (Figure 2).

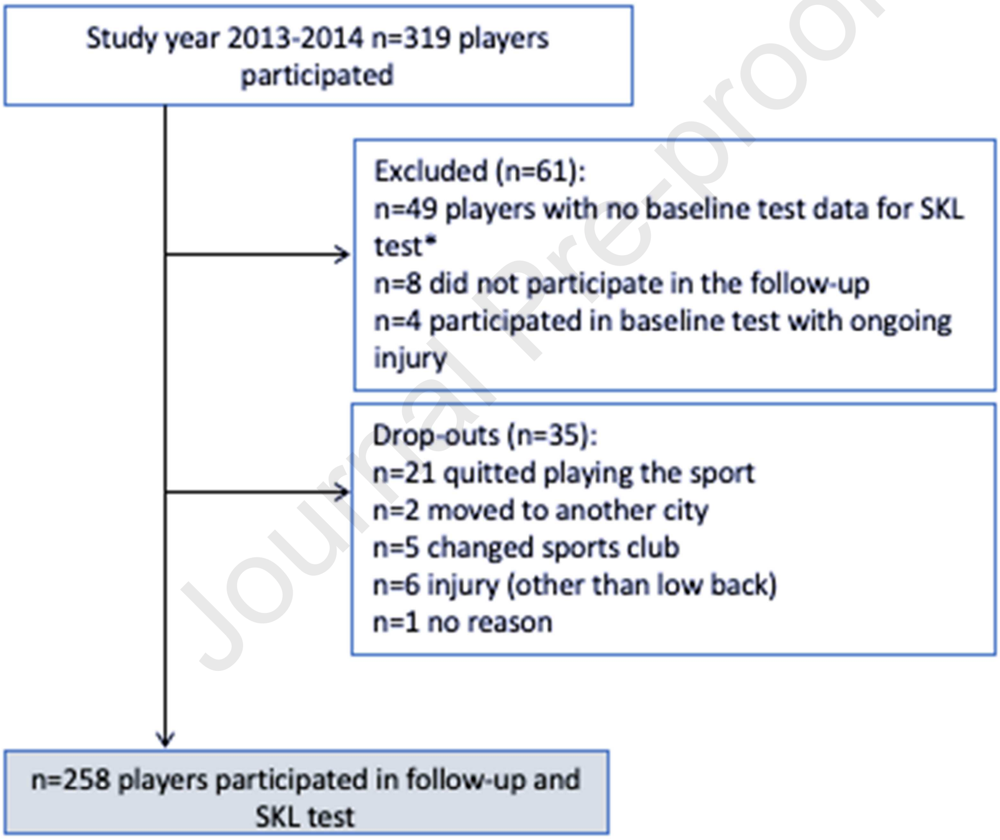

Figure 2. Study flow of the participating players. *Incomplete SKL test data (no testing data n=29, technical reasons n=16, incorrect performance n=4).

The baseline player demographics are presented in Table 2. Two-hundred-and-fifty-eight players participated in the follow-up and SKL test. The mean, minimum and maximum values for the investigated risk factors are presented in Table 3. There was a small number of players (n=40) with actual pelvic drop movements, and the maximum pelvic drop was 3.5 degrees.

Table 2. Baseline characteristics (n=258)

Variables	**Basketball**		**Floorball**		**P-value**
	Female (n=61)	**Male (n=67)**	**Female (n=50)**	**Male (n=80)**	
Age, years (mean, (SD))	14.4 (1.3)	15.1 (1.8)	17.3 (1.8)	16.9 (1.3)	≤0.001
Height, cm (mean, SD)	168.5 (6.5)	179.2 (10.3)	167.0 (6.0)	177.3 (6.0)	0.633
Weight, kg (mean, SD)	60.9 (8.6)	68.2 (13.8)	62.3 (7.6)	69.2 (8.6)	0.087
BMI (mean, SD)	21.4 (2.7)	21.0 (3.0)	22.3 (2.5)	21.9 (2.2)	0.003
Playing years (mean, SD)	6.6 (2.5)	6.8 (3.0)	7.2 (2.5)	8.8 (3.0)	≤0.001
Training hours * (mean, SD)	170.9 (73.4)	246.8 (134.6)	231.7 (106.4)	257.7 (133.5)	0.010
Game hours† (mean, SD)	7.6 (4.7)	7.5 (3.9)	10.7 (7.4)	10.0 (6.9)	0.001

Body mass index, BMI; SD, standard deviation.
p-values shown refer to the t-test/Mann-Whitney test between sports groups, including both sexes.
*Team practice hours/season.
† Active playing time in games during the season.

Table 3. Baseline test results for players with and without LBP during follow-up

Outcome	No LBP during follow-up[#]	LBP during follow-up (n=32)		All players		
Variables	Mean (95% CI)	Mean (95% CI)	P-value	Mean (95% CI)	Min. value	Max value
Right leg						
Peak pelvic anterior tilt, degrees[//]	9.6 (9.1 to 10.2)	9.3 (7.8 to 10.8)	0.854	9.6 (9.1 to 10.1)	0.7	20.6
Peak pelvic posterior tilt, degrees[//]	-4.3 (-5.1 to -3.5)	-4.0 (-6.0 to -2.0)	0.797	-4.2 (-4.9 to -3.5)	-23.3	9.9
Peak contralateral hike angle, degrees[^]	13.8 (13.4 to 14.2)	13.0 (11.9 to 14.1)	0.793	13.7 (13.3 to 14.1)	5.2	22.4
Peak contralateral	1.9 (1.6 to 2.1)	1.5 (0.7 to 2.3)	0.934	1.8 (1.6	-3.5	8.0

drop angle, degrees^				to 2.1)		
Left leg						
Peak pelvic anterior tilt, degrees[//]	9.2 (8.6 to 9.7)	9.4 (7.8 to 10.9)	0.691	9.2 (8.7 to 9.7)	-1.7	19.9
Peak pelvic posterior tilt, degrees[//]	-4.7 (-5.5 to -3.9)	-4.1 (-6.1 to -2.1)	0.814	-4.6 (-5.3 to -3.9)	-24.4	9.9
Peak contralateral hike angle, degrees^	14.2 (13.7 to 14.7)	13.9 (12.8 to 15.0)	0.189	14.1 (13.7 to 14.5)	6.5	27.0
Peak contralateral drop angle, degrees^	2.2 (1.9 to 2.5)	2.2 (1.5 to 2.9)	0.361	2.2 (2.0 to 2.3)	-3.4	8.9

LBP; low back pain, CI; confidence interval

[#] Because of an insufficient number of valid trials (< 2 valid trials), four players were excluded from the right side test and six players from the left side test. Right leg n=222, Left leg n=220.

[//] Positive value in pelvic tilt corresponds to pelvic anterior tilt and a negative value to pelvic posterior tilt.

^Positive value in pelvic obliquity corresponds to contralateral pelvic hike and a negative value to contralateral pelvic drop.

Time loss LBP was recorded 39 times during the 12-month follow-up in 35 players. Three of these were direct contact injuries (n=1 sacrum contusion, n=2 low back contusion) and, hence, were excluded from the analysis. LBP in 78% (n=25) of the players had gradual nontraumatic onset, and 22% (n=7) had acute traumatic onset. Seventy-six percent of the nontraumatic onset and 86% of the acute onset LBP resulted in at least an absence of seven days from normal training (mean (SD) nontraumatic onset LBP: 54.5±86.0, acute onset traumatic LBP 72.4±131.8 days). The median absence was 14 days, which corresponds to moderate severity (Fuller et al., 2006). The incidence of time loss LBP, including only the first episode of LBP during the follow-up, was 0.5 per 1000 player hours. The incidence rate was 12% in the floorball players and 12% in the basketball players. There were no statistically significant differences between the players with and without time loss LBP during the follow-up in the baseline characteristics (age, sex, height, weight, BMI, playing years, team training or game hours).

Risk factor analyses

The results from the univariate analyses are shown in Table 4. None of the investigated risk factors were associated with LBP in the univariate Cox analyses.

Table 4. Unadjusted hazard ratios (HRs) and confidence intervals (CIs) from the Cox mixed-effect analyses.

Risk factors	HR	95 % CI	P
Left leg			
Peak pelvic anterior tilt	1.00	(0.92, 1.09)	0.930
Peak pelvic posterior tilt#	0.98	(0.93, 1.05)	0.610
Peak contralateral hike angle	0.98	(0.89, 1.09)	0.710
Peak contralateral drop angle^	1.01	(0.85, 1.18)	0.950
Right leg			
Peak pelvic anterior tilt	0.98	(0.90, 1.07)	0.630
Peak pelvic posterior tilt#	0.99	(0.94, 1.06)	0.860
Peak contralateral hike angle	0.94	(0.85, 1.04)	0.250
Peak contralateral drop angle^	1.08	(0.90, 1.28)	0.410

HR calculated per one-degree increase.

#HR converted so that one-unit increase is interpreted as more pelvic posterior tilt.

^HR converted so that a one-unit increase is interpreted as more pelvic movement towards pelvic drop.

In the adjusted Cox regression analysis, no association between sagittal plane pelvic tilt and LBP was found when adjusted for a history of LBP and leg dominance (Figure 3). Furthermore, none of the analyses between pelvic obliquity and LBP revealed significant associations (Figure 4). The peak pelvic drop angle was also analysed as a categorised risk factor (no pelvic drop = contralateral pelvic drop values at zero or higher, small pelvic drop = contralateral pelvic drop values smaller than zero). The results showed no significant difference in risk between players with or without pelvic drop.

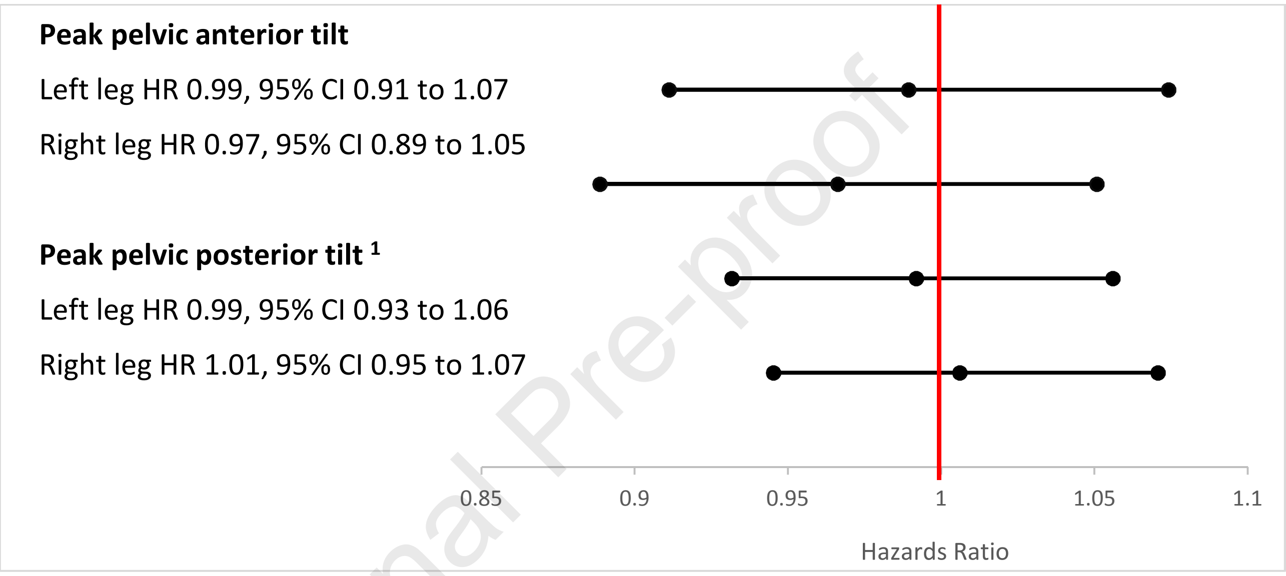

Figure 3. Adjusted hazard ratios (HR) and confidence intervals (CIs) from the Cox mixed-effect analyses with incidence of LBP as the outcome and peak pelvic tilt as a risk factor. Adjusted for history of LBP and leg dominance (unilateral leg dominance/bilateral leg dominance). ^{1} HR converted so that a one-unit increase is interpreted as more pelvic posterior tilt.

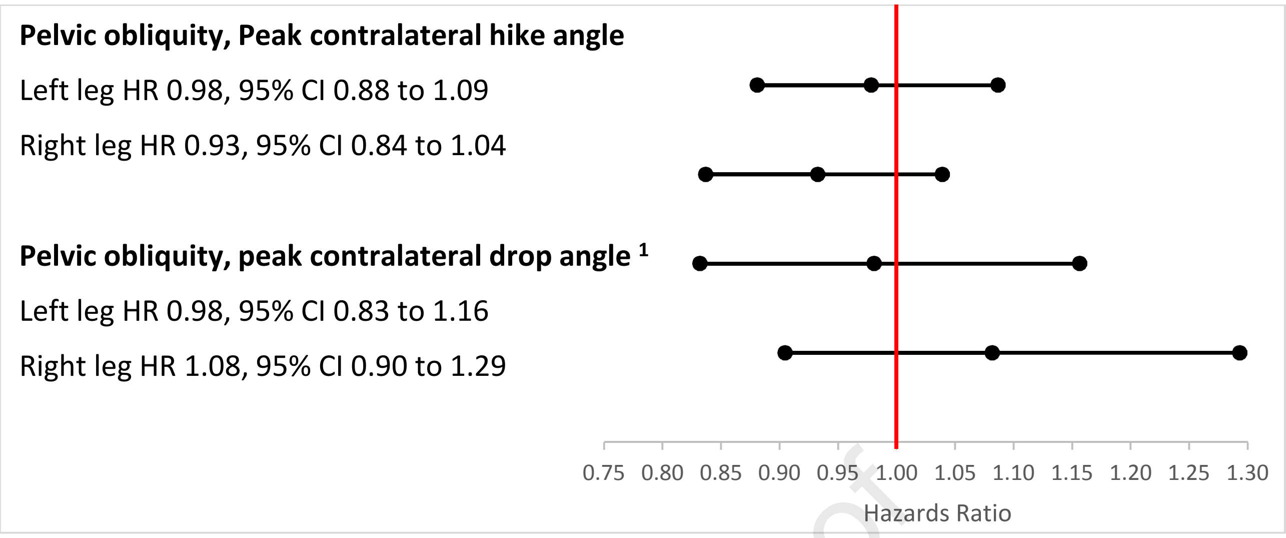

Figure 4. Adjusted hazard ratios (HR) and confidence intervals (CIs) from the Cox mixed-effect analyses with incidence of LBP as the outcome and peak pelvic obliquity as a risk factor. Adjusted for history of LBP and leg dominance (unilateral leg dominance/bilateral leg dominance). [1] HR converted so that a one-unit increase is interpreted as a smaller minimal value, that is, pelvic movement towards pelvic drop.

DISCUSSION

The current prospective study showed that sagittal plane pelvic tilt during the SKL test is not a risk factor for LBP in youth basketball and floorball players. We observed no association between LBP incidence and sagittal plane pelvic tilt or frontal plane pelvic obliquity during the SKL test, which was in opposition to our hypothesis.

Our hypothesis was that increased pelvic movement during the SKL test could result in compensatory movement in the low back area and increase the risk for LBP. In theory, increased pelvic movement might lead to increased load and strain in the low back area. Our hypothesis was based on the widely known kinematic chain theory, where movement in one section affects the other sections of the kinetic chain (Karandikar & Vargas, 2011); this theory is supported by Leppänen et al. (2020), who showed that pelvic hike during the SKL test increases the risk for knee injuries in youth athletes. In addition, it has previously been shown that lower extremity kinematics (Bayne, Elliott, Campbell, & Alderson, 2016) and movement control of the lumbo-pelvic area (Grosdent et al., 2016; Roussel et al., 2009) might be associated with LBP in youth athletes. For example, Roussel et al. (2009) prospectively investigated the relationship between movement control of the lumbo-pelvic area during hip movements and future lower extremity injuries and LBP; they observed an increased risk for lower extremity injuries and LBP in dancers with altered lumbo-pelvic movement control (Roussel et al., 2009). Chaudhari, McKenzie, Pan and Oñate (2014) observed increased odds for time loss from a sports injury in baseball pitchers with larger sagittal plane lumbo-pelvic movement during a single-leg raise test in standing. We were unable to find significant risk factors in pelvic kinematics during hip flexion movement in youth basketball and floorball players using the SKL test. Our results are in line with those of Olivier, Stewart, Olorunju and McKinon (2015), who noticed that lumbo-pelvic movement control did not predict injuries in cricket players.

We hypothesised that increased pelvic obliquity might predispose players to LBP because earlier studies suggest that pelvic obliquity can increase facet joint forces and disc pressure (Popovich et al., 2013). However, we did not find an association between pelvic obliquity and LBP. This might be because the data presented only a few and minimal values of pelvic drop. On the other hand, the data show that excessive pelvic drop during the SKL test is not common in youth basketball and floorball players and that the SKL test might not be suitable for detecting players with altered pelvic control during single-leg tasks.

In the present study, we did not consider that the risk factors for LBP might differ based on many factors, such as tissue injury, onset mechanism, sports-specific requirements, symptom picture, such as pain provoked by certain movement directions, as well as other characteristics of LBP and the characteristics of the players, such as sex. For example, when investigating LBP—irrespective of the onset or duration of LBP or presence or absence of movement control impairments and provocative movement directions (Astfalck et al., 2010; Dankaerts, O'Sullivan, Burnett, & Straker, 2006)—this so-called ‘wash out’ effect may happen. For example, when investigating nonspecific LBP classified into subgroups based on the presence of movement control impairments and provocative movement directions, differences in movement patterns in people with and without LBP can be seen (Astfalck et al., 2010; Dankaerts et al., 2006; Dankaerts et al., 2009). Thus, it might be beneficial to investigate risk factors for LBP in different kinds of LBP and subgroups.

Furthermore, LBP complaints are a heterogeneous group, and with most of the complaints, the exact cause for pain cannot be identified. Also, psychosocial factors affect the pain experience. This makes it more difficult to subgroup LBP based on, for example, injured tissue and, hence, to identify risk factors for LBP complaints.

For the Cox analysis, we did not enter all adjusting factors available, such as age, sex, BMI and family history of LBP, into the final risk factor analyses, even though prior studies have stated them as plausible predisposing factors for LBP (Ferreira, Beckenkamp, Maher, Hopper, & Ferreira, 2013; Kamper et al., 2017). This was because of applying the rule of 10 incidents per variable in the model (Peduzzi et al., 1995; Peduzzi et al., 1996). We included age, sex, BMI, nicotine use, leg dominance, family history of LBP and history of LBP in the same model, and one by one, we dropped the least significant variables from the model. We noticed that only nicotine use, history of LBP and leg dominance were statistically significant factors. Interestingly, sex, age and BMI were not statistically significant. History of LBP and leg dominance had the lowest p-value and were included in the final adjusted analyses. Out of curiosity, we also ran the analyses using nicotine and history of LBP as adjusting factors, but the results remained the same.

Strengths and limitations

The strengths of this investigation were the 12-month follow-up and prospective registration of the individual training hours, game hours and LBP complaints. The sample can also be seen as representative of youth basketball and floorball players of the same level in Finland.

Despite the strengths, there are also limitations to consider. We did not perform a reliability analysis of the 3D SKL test. However, one trained physiotherapist performed the marker placement, which decreased the risk of error because of inconsistent marker placements. Aberrant marker movement can also affect the results in a 3D movement analysis, and ASIS markers have been shown to have relatively more artefacts compared with PSIS (Hara, Sangeux, Baker, & McGinley, 2013).

Also, the starting leg was not randomised, so the players might have been more familiar with the test when performing the test on their dominant leg. In addition, even though the players were asked to lift their knee to a horizontal position (hip to 90 degrees flexion), we also included players who bent their hip only to 45 degrees while lifting their knee. This might have affected the results because it is very likely that the movement of the pelvis changes if one lifts the knee into 90 degrees hip flexion instead of 45 degrees hip flexion.

Our sample size and number of events were relatively small, and it is possible that there was not enough statistical power to detect small to moderate associations. Bahr et al. (Bahr & Holme, 2003) stated that one would need 30 to 40 events to detect moderate to strong associations and more than 200 events for small to moderate associations. Because of the sample size, we did not stratify the analyses by sex. Thus, we added sex to the risk factor models, but because sex was an insignificant covariate, it was dropped from the final models. However, in future investigations, it would be better to explore the risk factors for LBP in more homogenous samples, such as within one sport or females or males separately.

Because we investigated the risk factors for LBP resulting in time loss from training and games, it should be noted that the results might be different if all low back complaints were included. If the OSTRC questionnaire were used, we could have captured more injuries affecting the player in different ways (Clarsen, Myklebust, & Bahr, 2013). For example, Clarsen et al. (2015) has shown that back pain complaints are very common in the athletic population of young adults and youth and do not often lead to absence from sport activity, even though they can affect participation and performance. Using time loss as a determinator of severity might underestimate the influence of psycho-social factors (e.g., fear avoidance) when a player is unable to fully participate in training and games. The OSTRC questionnaire gives more information on how the player has perceived LBP to affect their participation.

The aetiology of LBP has been shown to be multifactorial, meaning that in addition to external loading, internal loading such as psychosocial stress, as well as other socioeconomic, health and health–behaviour factors, should also be considered and recorded in future LBP studies focusing on youth athletes.

CONCLUSIONS

The SKL test, as measured in the current study, is not a useful screening test to identify youth basketball and floorball players at increased risk for future LBP.

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HIGHLIGHTS

- The association between LBP and pelvic kinematics in youth floorball and basketball players was investigated in this cohort study.
- Three-dimensional movement analysis was used, and pelvic kinematics were calculated from standing knee lift test.
- Individual training and game hours and time-loss LBP were recorded during the 12-month follow-up.
- Neither pelvic tilt, or obliquity, during standing knee lift test were associated with future LBP in youth floorball and basketball players.

Ethical approval Ethics Committee of Pirkanmaa Hospital District (ETL-code R10169). The study was carried out in accordance with the Declaration of Helsinki and the guidelines for good scientific practice.

Conflict of Interest None to declare

Ethical Statements Ethics Committee of Pirkanmaa Hospital District (ETL-code R10169). The study was carried out in accordance with the Declaration of Helsinki and the guidelines for good scientific practice.

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Availability of data and materials The data can not be shared because permission was not asked from the participants or their parents.

Authors' contributions All authors contributed to study concept and design. KP was responsible for conducting the data acquisition. ML was responsible for preparation of the 3D motion capture data. MR was responsible for the main data analysis, interpretation and writing the first draft of the manuscript. KP, AH, SÄ, ML, GM, TV, PK, and JP were significant manuscript revisers. All authors have approved the submitted version of the manuscript. KP is the guarantor.