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Standing knee lift test is not a useful screening tool for time-loss LBP in youth basketball and floorball players

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ABSTRACT

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

Design A Prospective cohort study.

Setting Finnish youth floorball and basketball players.

Participants Finnish 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 during the 12-month follow-up and verified by a study physician. Associations between LBP and sagittal plane pelvic tilt and frontal plane pelvic obliquity during SKL test measured at baseline were investigated. Individual training and game hours were recorded and the Cox's proportional hazard models with mixed-effects were used for analysis.

Results Cox analyses revealed that sagittal plane pelvic tilt nor frontal plane pelvic obliquity, as measured in this study, were not associated with LBP in floorball and basketball players during the follow-up.

Conclusions Pelvic movement during standing knee lift test is not associated with future LBP in youth floorball and basketball players.

Keywords LBP, sports injury, risk factors, prospective study, youth athletes

INTRODUCTION

Low back pain (LBP) is common already in youth and results in absence from work or school, and interference with normal daily activities and recreational physical activities[1]. In Finland, nearly half of youth between 11 to 15-years participate in organized sports. Studies analysing any association between LBP and physical activity are inconsistent[2], but it seems that participation in organized sports might increase the risk for LBP[3]. However, prospective studies investigating risk factors for LBP in youth sports are limited. Yet, to be able to effectively prevent or decrease the incidence of LBP in youth athletes, risk factors should be identified.

LBP prevalence is high in youth floorball and basketball players[4]. Both sports include running, sudden turns and stops as well as other movements performed in single-leg support. Standing knee lift (SKL) test has been used to evaluate hip and pelvic stability [5-8]. The test is often used in clinics especially with LBP population to assess hip and pelvic stability and has been suggested as a part of functional screening for athletes[7]. Increased pelvic movement during the test may be due to impaired movement control which may lead to increased loading and strain in the low back area.

Further investigation analysing any association between LBP and movement patterns in sport is needed[9]. The overall aim of this explorative study was to investigate the association between LBP incidence and pelvic kinematics during standing knee lift in youth floorball and basketball players. The main objective was to assess, whether increased sagittal plane pelvic tilt during SKL test predisposes for LBP in youth floorball and basketball players. The secondary objective was to explore whether frontal plane pelvic kinematics during SKL test are associated with LBP incidence. Our hypothesis was that players with increased pelvic movement during SKL test have increased risk for LBP.

METHODS

This prospective cohort study was approved by Ethics committee of Tampere 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 participants (and legal guardian if player was under 18 years old).

Participants and data collection

This 12-month follow-up study is part of a larger three-year follow-up study investigating lower extremity (LE) injuries in youth floorball and basketball players (PROFITS)[10]. Players who were ineligible junior league players (older than 21-years-old), had an ongoing acute injury affecting the baseline test participation or did not participate in the test or in follow-up were excluded from this study.

The baseline questionnaire was answered and the baseline tests[10] 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 players' history of LBP was recorded using the Standardized Nordic questionnaire of musculoskeletal symptoms (modified version for athletes)[11,12]. History of previous LBP was determined based on question 'How many days have you had LBP during the past 12 months: 'none' recorded as no LBP history and , '1 to 7 days', '8 to 30 days', '>30 days but not daily' and 'daily' recorded as a history of LBP.

Test procedure

Standing knee lift (SKL) test was used to assess hip and pelvic stability. This test is a modified Trendelenburg test[6] and is often used as a clinical screening test for LBP patients. For the purposes of this study 3D motion analysis was used to reveal the performance in the SKL test. The 3D motion analysis comprised of 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 was recorded synchronously at 300 fps and 1500 Hz.

Prior 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 shoe on second metatarsal and calcaneus) and a static calibration trial was performed.

During the test the players stood with feet 20 cm apart (standardized 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 by flexing hip and knee and hold the position for few seconds. The player was instructed to lift the knee to horizontal level. The trial was regarded valid if the player lifted the lifted the leg to at least 45 degrees hip flexion and all markers stayed firmly on the player's skin throughout the test. The test started by lifting the dominant leg and followed by the non-dominant leg. The leg dominance was determined by asking about their preferred kicking leg. Trials were excluded if the hip angle was below 45 degrees or the standing foot was moved.

Vicon Nexus Plug-in Gait model was used for the analyses. All the kinetic measurements were performed from foot lift to foot contact, i.e. 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 pelvic orientations from 3D marker trajectories. For reading and modifying motion capture and force plate acquisitions, an open-source Python wrapping of Biomechanical ToolKit platform (BTK 0.3) was used. A standard, open-source, Python libraries for scientific computing (NumPy 1.15.4), data analysis (pandas 0.19.2), and data visualization (Matplotlib 2.0.0) where utilized 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 a 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. 25N was set as the threshold value. All incorrect or incomplete recordings were removed prior to analysis as 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.

For all investigated risk factors, the mean of two trials was calculated for right and left legs. The primary kinematic factor investigated was sagittal plane pelvic movement, and the following variables were calculated; peak pelvic anterior tilt and peak pelvic posterior tilt. For the sub-analysis the secondary independent factor investigated was frontal plane pelvic obliquity and the following predefined variables were calculated; peak contralateral pelvic hike angle (maximum value of pelvic obliquity) and peak contralateral pelvic drop angle (minimum value of pelvic obliquity). The variables are described in TABLE 1.

TABLE 1. Investigated primary and secondary risk factors

Variables	Description	Interpretation of values
Primary independent variables		
Peak pelvic anterior tilt	Maximal point of anterior tilt in relation to global vertical line during the knee lift (mean of two trials).	Positive value = Pelvic tilts anteriorly. 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).	
Secondary independent variables		
Pelvic obliquity - Peak contralateral drop angle	Angle between horizontal 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= contralateral pelvic hike (ASIS stays above horizontal line).
Pelvic obliquity - Peak contralateral hike angle	Angle between 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).	

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 team practices and games for at least 24-hours. Direct contact injuries were excluded from this investigation. A direct contact injury was defined as LBP sustained as a result of direct contact to the lower back[13] (e.g. blow to the lower back).

Two study physicians contacted the teams weekly to interview the injured players. Information on new complaints was collected using a structured injury questionnaire (Supplementary table 1.) based on Fuller et al's[14] recommendations. During the follow-up, coaches recorded all individual team practice and game hours for every player.

Statistical methods

IBM SPSS Statistics (v. 23-24.0) and Chi-square test and the t-test (Mann-Whitney test when appropriate) were used for descriptive statistical analyses and the results were reported as the mean, standard deviation (SD), and 95% confidence intervals (CI).

Cox's proportional hazard model with mixed-effects was used to study the relationship between investigated risk factors and LBP incidence. The analyses were performed using R (v 3.1.2; R Foundation for Statistical Computing[15]) and package coxme[16]. 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 (LBP) or the end of follow-up (if no event) were included in the Cox analyses. Data from all eligible players entering the follow-up was included in the analyses for the time they participated.

Univariate analyses were followed by multivariable analyses. It has been recommended to have 10 events per included variable in the Cox analyses[17,18] and therefore two adjusting variables were selected from the following factors: age, sex, BMI, nicotine use, leg dominance, family history of LBP, and history of LBP. Leg dominance was used as two category variable; the categories 'left' and 'right' were merged into 'unilateral leg dominance' and category 'don't know/both' into 'bilateral/unknown leg dominance'. The adjusting factors were selected by dropping factors from the model one by one, based on their statistical significance. Only nicotine use, history of LBP and leg dominance showed a statistically significant association with LBP. Finally, history of

LBP and leg dominance were entered into the final model. The results are presented as hazard ratios (HR), 95% CIs and p-values. Player was considered as unit of analysis and results for right and left legs were performed separately.

RESULTS

Nine basketball and nine floorball teams participated in the study. 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 1).

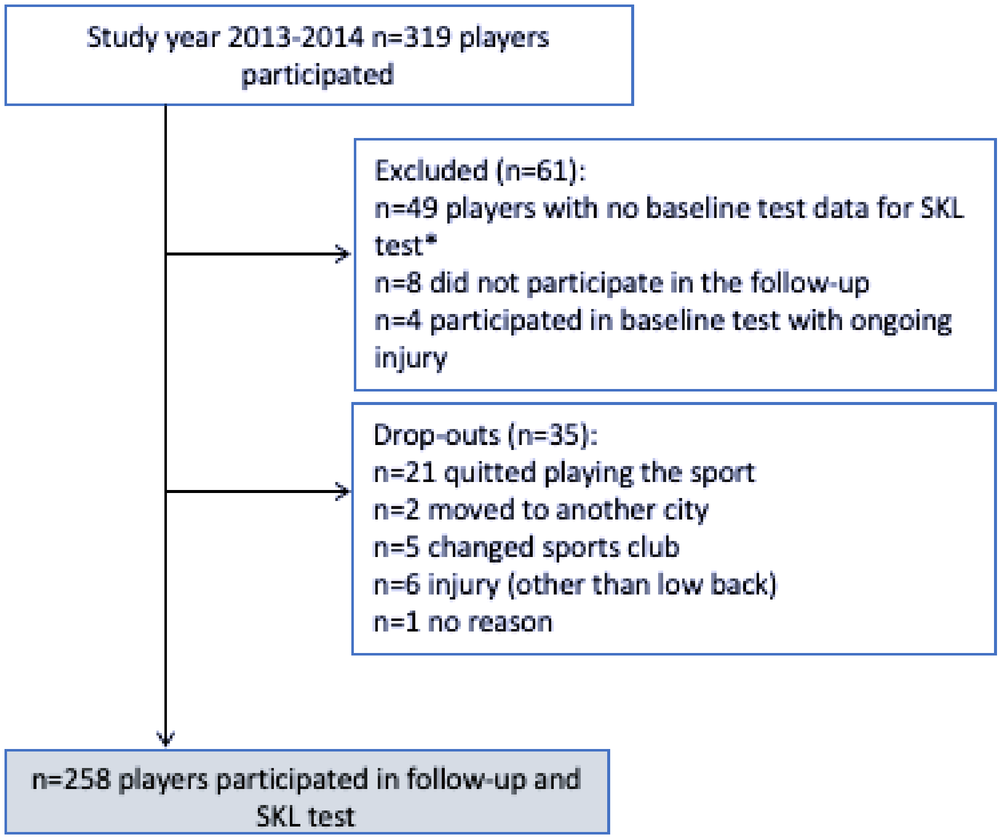

FIGURE 1. Study flow of participants. * Incomplete SKL test data (no testing data n=29, technical reasons n=16, incorrect performance n=4).

Right side test was excluded from four players and left side test from six players for having only one valid trial. The baseline player demographics are presented in TABLE 2. The mean, minimum and maximum values for the investigated primary and secondary variables are presented in TABLE 3. There was a small number of players (n=40) with actual pelvic drop and 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, yrs (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

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 in players with and without LBP during follow-up

Outcome	No LBP during follow-up (n=220)	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
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
Sub-analysis						
Right leg*						
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 drop angle, degrees	1.9 (1.6 to 2.1)	1.5 (0.7 to 2.3)	0.934	1.8 (1.6 to 2.1)	-3.5	8.0
Left leg †						
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,
* n= 254
† n= 252

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 were excluded from this analysis. LBP in 78 % (n=25) of the players had gradual non-traumatic onset and 22 % (n=7) had acute traumatic onset. 76 % of the non-traumatic onset and 86 % of acute onset LBP resulted in at least seven days absence from normal training (mean (SD) non-traumatic onset LBP: 54.5±86.0, acute onset traumatic LBP 72.4±131.8 days). Median absence was

14 days. The incidence of time-loss LBP, including only the first episode of LBP during the follow-up, was 0.5 per 1000 player-hours.

Risk factor analyses

The results from 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 (HR) and confidence intervals (CIs) from Cox mixed-effect analyses.

Primary variables	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
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
Secondary variables			
Left leg			
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 contralateral hike angle	0.94	(0.85, 1.04)	0.250
Peak contralateral drop angle	1.08	(0.90, 1.28)	0.410

In the adjusted Cox regression analysis, no association between sagittal plane pelvic tilt and LBP was found when adjusted with history of LBP and leg dominance (FIGURE 2). Furthermore, none of the secondary exploratory analyses between pelvic obliquity and LBP revealed significant associations (FIGURE 3). Peak pelvic drop angle was analysed also as categorized risk factor (No pelvic drop= CL pelvic drop values at zero or higher, Small pelvic drop= CL pelvic drop values smaller than zero). The results showed no significant difference in risk between players with or without pelvic drop.

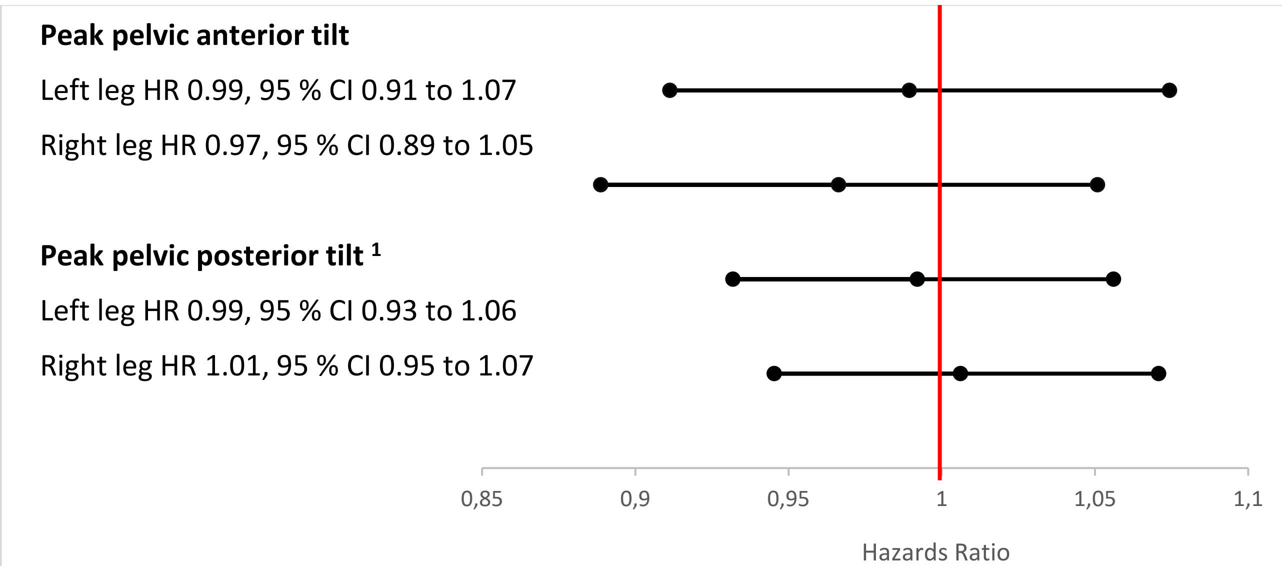

FIGURE 2. Adjusted Hazard ratios (HR) and confidence intervals (CIs) from the primary Cox mixed-effect analyses with incidence of LBP as outcome. Adjusted with history LBP and leg

dominance (unilateral leg dominance/bilateral leg dominance). [1] HR converted so that one-unit increase is interpreted as more pelvic posterior tilt

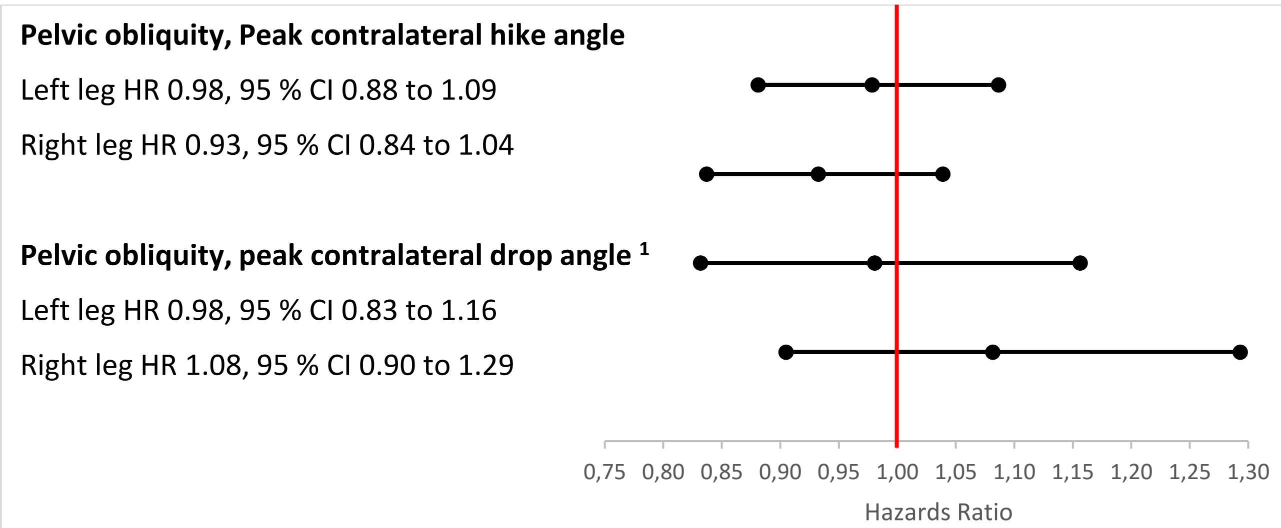

FIGURE 3. Adjusted Hazard ratios (HR) and confidence intervals (CIs) from the secondary Cox mixed-effect analyses with incidence of LBP as outcome. Adjusted with history LBP and leg dominance (unilateral leg dominance/bilateral leg dominance). [1] HR converted so that one-unit increase is interpreted as smaller minimal value, i.e. pelvic movement towards pelvic drop.

DISCUSSION

This prospective study showed that sagittal plane pelvic tilt during standing knee lift test is not a risk factor for LBP in youth basketball and floorball players. We observed no association between pelvic tilt during standing knee lift test, oppose to our hypothesis. In addition, the secondary explorative analysis with frontal plane pelvic kinematics revealed no potential risk factors for LBP.

Our hypothesis was that increased pelvic movement during standing knee lift test could increase the risk for LBP plausibly due to compensatory movement in the low back resulting in increased load and strain. Our hypothesis was based on the widely known kinematic chain theory, where movement in one section affects the other sections of the kinetic chain[19]. In addition, previously it has been shown that lower extremity kinematics[20] and movement control of the lumbo-pelvic area[21,22] might be associated with LBP in youth athletes. For example, Roussel et al.[21] investigated prospectively the relationship between movement control of lumbo-pelvic area during hip movements and future lower extremity injuries (LEI) and LBP. They observed increased risk for LEI and LBP in dancers with impaired movement control of the lumbo-pelvic area in two movement control tests[21]. Chaudhari et al. observed increased odds for time-loss sports injury in baseball pitchers with larger sagittal plane lumbo-pelvic movement during a single leg raise test in standing [23]. We were unable to find significant risk factors in pelvic kinematics during hip flexion movement in youth basketball and floorball players using the standing knee lift test. Our results are in line with results from Oliver et al. who noticed that lumbo-pelvic movement control did not predict injuries in cricket players[24].

Our secondary aim was to look into association between frontal plane obliquity and LBP. We did not find an association between pelvic obliquity and LBP, however the data presented only few and minimal values of pelvic drop. On the other hand, the data suggested that excessive pelvic drop during static single leg stance might not be common in youth basketball and floorball players.

In this study we investigated if hip-pelvic kinematics are associated with time-loss LBP and we analysed non-traumatic gradual onset LBP separate for all LBP. However, we did not consider whether the association could be different between hip-pelvic kinematics and LBP that is subgrouped based on other characteristics of the LBP. However, when investigating LBP irrespective of the onset or duration of LBP or presence or absence of movement control impairments (MCI) and provocative movement directions[25,26] this so called "wash out" effect may happen. When investigating non-specific LBP classified into subgroups based on presence of MCI and provocative movement directions, differences in movement patterns in people with and without LBP can be seen[25-27]. Thus, it might be beneficial to investigate whether certain movement patterns are risk factors for LBP where pain is provoked by certain movement directions. However, in order to be able to classify the LBP reported by the players, we would need to record more data of the inquired LBP, such as symptom provocation and relief and test for movement control impairments.

The other reason for insignificant findings is probably our too narrow scope, i.e. looking just at one part of the body and ignoring compensations distally. For example, Dingenen et al. demonstrated three patters of movement in SLS test in athletes with trunk dominant, lower extremity dominant and combined[28].

For the Cox analysis, we did not enter all adjusting factors available, such as age, sex, BMI and family history of LBP even though previous literature has stated them as plausible predisposing factors for LBP[2,29]. This was due to applying the rule of ten incidents per variable in the model. Interestingly, when we added age, sex, BMI, nicotine use, leg dominance, family history of LBP, and history of LBP into the same model and dropped non-significant variables one-by-one we noticed that only nicotine use, history of LBP and leg dominance were found to be statistically significant factors.

Strengths and limitations

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

Despite the strengths, there were also limitations to consider. We did not perform a reliability analysis of the 3D standing knee lift test. However, one trained physiotherapist performed the marker placement, which decreased the risk for error due to unconcise marker placements. Aberrant marker movement can also affect results in 3D movement analysis and ASIS markers have shown to have relatively more artefact compared to PSIS[30].

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. Because of the sample size, we did not stratify the analyses by sex. Thus, we added sex to the risk factor models, but since sex was an insignificant covariate, it was dropped from the final models. Furthermore, one limitation is that there were athletes taking part in injury surveillance, but not participating in the knee lift test.

As we investigated risk factors for time-loss LBP, it should be noted that the results might be different if all low back complaints were included in this study. If OSTRC questionnaire was used, we could have captured more injuries affecting the player in different ways[31]. For example, Clarsen et al. has shown that back pain complaints are very common in athletic population of young adults and youth and does not often lead to absence from sport[32].

CONCLUSIONS

Standing knee lift test, as measured in this study, is not a useful screening test to identify youth basketball and floorball players at increased risk for future LBP. Since people with LBP have been shown to be a heterogenic group in previous studies, assessment of risk factors for all LBP symptoms together (without LBP classification) might not be a reasonable approach in future investigations.

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