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No association between static and dynamic postural control and ACL injury risk among female elite handball and football players – a prospective study of 838 players

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Abstract

Background: Research on balance measures as potential risk factors for ACL injury is limited.

Objective: To assess whether postural control was associated with an increased risk for ACL injuries in female elite handball and football players.

Method: Premier league players were tested in the pre-season and followed prospectively for ACL injury risk from 2007 through 2015. At baseline, we recorded player demographics, playing experience, ACL and ankle injury history. We measured center of pressure velocity in single-leg stabilization tests and reach distances in the Star Excursion Balance Test. To examine the stability of postural control measures over time, we examined their short- and long-term reproducibility. We generated logistic regression models, one for each of the proposed risk factors.

Results: A total of 55 (6.6%) out of 838 players (age: 21±4 yrs; height: 170±6 cm; body mass: 66±8 kg) sustained a non-contact ACL injury after baseline testing (1.8±1.8 yrs). When comparing normalized balance measures between injured and uninjured players in univariate analyses, none of the variables were statistically associated with ACL injury risk. Short- and long-term reproducibility of the selected variables was poor. Players with a previous ACL injury had a 3-fold higher risk of sustaining a new ACL injury compared to previously uninjured players (OR 2.9, CI 1.4 to 5.7).

Conclusion: None of postural control measures examined were associated with increased ACL injury risk among female elite handball and football players. Hence, the variables included in the current investigation cannot be used to predict injury risk.

Introduction

Although the etiology of ACL injuries is not fully understood, they are likely multifactorial in nature, thought to be related to a combination of neuromuscular, biomechanical, anatomical, hormonal and genetic factors.[1,2] Typically, ACL injuries occur in pivoting sports characterized by rapid changes of direction and frequent single-leg landings, often with the athlete out of balance and almost always without direct contact to the knee.[3-6] Postural control has been suggested to play a crucial role in injury causation[6-8] although the association between knee kinematics and future ACL injury risk seems to be weak.[9]

The role of balance is believed to be a critical component of neuromuscular control[10] and as a modifiable risk factor contributes to limit medio-lateral knee displacement and loading during dynamic activities.[11,12] Balance exercises seem to represent a key component of effective ACL injury prevention programs, which tend to focus on frontal plane knee control during static and dynamic tasks.[13-16] Also, clinicians often use postural control to evaluate deficits resulting from injury and the progress during rehabilitation protocols.[17]

The Star Excursion Balance Test (SEBT) challenges lower limb strength and range of motion and is widely used as a clinical assessment tool for dynamic balance and postural control.[18,19] Reduced performance in the SEBT, displayed as lower reach distances, has also been linked to an increased likelihood of lower limb injuries.[20]

In a small prospective cohort study on 278 NCAA div 1 college athletes (9 ACL injuries), baseline time to stabilization for backward, forward, medial, and lateral single-leg jump landing tasks were assessed, and the odds ratio for an ACL injury increased 3-fold for every second these athletes took longer to stabilize following backward jump landing, indicating a significant, albeit weak, association between poor postural control and ACL injury risk.[21]

To date, little research exists quantifying balance measures as potential risk factors for ACL injury. Thus, the purpose of this prospective cohort study was to assess whether static and dynamic postural control were associated with an increased risk for ACL injuries in female elite handball and football players.

Methods

Study design and participants

This investigation represents secondary analyses of data from a cohort study designed to examine risk factors for noncontact ACL injuries in female elite handball and football players.[22] Data were collected over an 8-year period (2007-2015). Players with a first-team contract who were expected to play in the premier league during the 2007 season were eligible for participation. From 2008 through 2014, new teams advancing to the premier league and new players from included teams were invited for pre-season tests. From 2009, we also included football players from the female premier league. In total, we have baseline screening data of 429 handball and 451 football players, of which 838 players were included in the current paper (Figure 1).

We recorded all complete ACL injuries from the start of screening tests in 2007,through May 2015. For any ACL injury occurring during regular team training or competition, we contacted the injured player by phone to obtain detailed medical data and a description of the injury situation. The injury mechanisms were self-reported as contact (i.e. direct contact to the lower extremity), indirect contact (i.e. contact with other body parts) or non-contact. Injuries were categorized into two groups, non-contact/indirect contact or contact.[6] All ACL injuries were verified by MRI and/or arthroscopy.

Risk factor screening tests

The balance tests included in the present study were part of a comprehensive test battery to assess potential demographic, neuromuscular, biomechanical, anatomical, and genetic risk factors for an ACL injury. The screening tests were conducted at the Norwegian School of Sport Sciences in the pre-season: June through August for handball and February through March for football. Each player spent about 7 h in total to complete the screening, which also included information, warm-up trials, as well as a lunch break. We asked all players to complete a questionnaire to collect data on demographics, elite playing experience, histories of any previous injuries to the ACL or ankle injuries one year prior to testing. To examine the short- and long-term reproducibility of the selected balance tests, we also assessed two groups of athletes twice.

Single-leg stabilization

We quantified balance based on center of pressure (COP) measures on a balance platform (Good Balance system, Metitur Ltd, Jyväskylä, Finland). The Good Balance force platform system is an equilateral triangle (800 mm) that is connected to a 3-channel DC amplifier with an A/D converter and uses a sampling frequency of 200 Hz. During two types of single-leg balance tests, we measured the mean velocity of COP in medio-lateral (ML) and anterior-posterior (AP) directions (mm/s), as well as the area of the 95% confidence ellipse (mm^2). To control for the possible influence of the higher COP excursions among taller players, we adjusted the results for objectively measured player height (cm).

Starting on the preferred kicking leg, we asked the players to maintain balance for 20 s with arms resting in front of the body while standing on an unstable surface (Airex foams, 40 cm x 50 cm, 7 cm thick; Alusuisse Airex, Sins, Switzerland) in 1) a purely static position on 1 foam pad, and 2) following a drop down from 30 cm height, stabilizing on 2 foams on top of each other. The test order was the same for all players. To assess landing stability, the drop down test was added to the screening battery in 2009. All players were allowed one practice trial. For both types of tests, the trial was discarded and repeated if the player 1) failed to maintain unilateral stance by moving the stance foot from the initial position, 2) removed the resting arms from the front of her body, 3) got support from the contralateral leg by touching the testing leg. The mean value of 2 trials for each leg was kept for analyses.

We used the simplified Star Excursion Balance Test (SEBT)[23] to assess dynamic stability and postural control, combined with lower limb strength and range of motion. From a center point, 3 tape measures were attached to the floor in the anteromedial, medial and posteromedial directions. The medial direction was oriented perpendicular to the foot placed on the tape measure, and relative to this tape measure, the anteromedial and posteromedial directions were at a 45° angle.

While maintaining a single-legged stance on the tape measure, the grid midpoint, we asked the player with hands on her waist to reach as far as possible with her contralateral leg in all 3 directions, starting anteriorly and moving posteriorly in 3 separate trials. There were no instructions given on lower limb control while balancing; however, hands had to be held at the waist during the testing. Starting with balancing on the preferred kicking leg, we measured the maximal reach distance (to the closest cm) to the point where the most distal part of the contralateral foot reached. All players were allowed one practice trial in each direction. The trial was discarded and repeated if the player 1) failed to maintain unilateral stance by lifting or moving the stance foot from the grid, 2) removed her hands from the waist, 3) touched down with the reach foot and thereby failing to return the reach foot to the starting position. The mean out of 3 trials in each direction, normalized for leg length, was included in the analyses. Leg length was measured as the distance from hip joint center to malleolus as part of 3D motion analysis. The composite score was calculated by averaging normalized reach distances across the three directions.[24]

Ethics approval

The Regional Committee for Medical Research Ethics, South-Eastern Norway Regional Health Authority and the Norwegian Social Science Data Services approved the study. Players signed a written informed consent form before inclusion, including parental consent for players aged <18 yrs.

Statistical protocol

Data were analyzed using STATA, version 12 (StataCorp, College station, Texas, USA), and descriptive data are presented as means with standard deviations (SD) and frequencies with corresponding percentages. Balance measures are presented as absolute and normalized values. For players sustaining more than one ACL injury following baseline testing, we only included their first non-contact injury as the main outcome in the analyses.

Demographic data and baseline screening results were compared between players with and without a new ACL injury using chi-square tests for categorical data, Student's t-test for continuous variables when the criterion of independency was fulfilled, or by using robust regression models to account for dependencies between legs. We calculated odds ratios (OR) with 95% confidence intervals (CI) for players with and without ACL and ankle injury history. For the final analyses, the significance level was set at P<.05.

We selected our candidate variables according to hypotheses taken from the literature and followed a protocol with pre-defined procedures: Following the univariate analyses, we intended to investigate all candidate risk factors with a P-value of <.20 further in a multivariate regression model to explore the association between candidate risk factors and

ACL injury, and to adjust for differences in: 1) sport, 2) ACL injury history, and 3) ankle injury history.

To examine the stability of balance/postural control measures over time, we retested 144 players (aged 20.9±3.2 yrs) 1 to 5 yrs after the first test session (2.2±0.8 yrs). We also examined short-term reproducibility on 42 similar age elite level ball sport athletes and sport and exercise students; 26 of these completed the re-test session within 3 to 10 days, while 16 completed the re-test session 6 to 7 weeks after the first test session. We calculated the mean test difference, the standard method error (SEM) and the minimal detectable change (MDC).

Results

A total of 838 players were included in the final analyses, 409 handball and 429 football players (Figure 1). Player demographics and injury history are presented in Table 1.

During follow-up through May 2016, we recorded 80 ACL injuries in 67 players. Of those, 12 players sustained multiple ACL injuries after baseline testing (11 players with 2 injuries and one player with 3 injuries). Of the 67 index injuries suffered by these players, we recorded 9 as contact and 58 as non-contact/indirect contact. Three players with a non-contact injury had to be excluded due to missing postural control data, leaving us with 55 non-contact ACL injuries for analyses. The mean time between balance testing and a non-contact ACL injury was 1.8±1.8 yrs.

Players with a new ACL injury following testing did not differ significantly from those who remained free from ACL injury for any of the demographic or training history data. Twelve players with a history of previous ACL injury (3.5 ± 2.5 yrs before baseline screening) sustained a new ACL rupture; 4 of these re-ruptured the same knee and 8 suffered an ACL injury to the contralateral knee.

Univariate risk analysis

Among the 55 players who went on to suffer a new ACL injury, there was no difference between their injured and uninjured leg for any of the postural sway or dynamic balance measurements ($P>.05$) (Table 2). This was also the case when we repeated the analyses after removing all players with a previous ACL injury. The OR of sustaining a new ACL injury among those with a previous ACL injury compared to those with no ACL injury history was 2.86 (95% CI 1.44 to 5.69).

A total of 377 players (45%) reported at least one ankle injury during the previous year, but there was no difference in ACL injury risk between players with or without a history of ankle injury (P=.46), including the number of ankle sprains during the year preceding testing (P=.16).

When comparing normalized postural sway and balance measures between injured and uninjured legs, none of the selected variables turned out to be candidate risk factors in univariate risk analyses (P>.20) (Table 3). Therefore, we did not conduct multivariate analyses. This was also the case when we repeated the analyses after removing all players with a history of previous ACL injury.

Change of postural control measures over time (reproducibility)

With an average time of 2.2 (SD 0.8) years between the 2 test sessions for 144 elite level players, systematic improvements were observed in postural control measures (1-14% for postural sway measures, and 3-4% for functional balance). However, for both postural control measures, the random error was greater than the systematic change, as shown by the SEM and MDC values (Table 4). The same was the case for the short-term reproducibility (Table 5).

Discussion

The main findings of this large prospective cohort study to better understand the etiology of ACL injury do not lend support to postural control as risk factors of importance. Following female elite athletes to ACL injuries as main outcome measure, we could not detect any association between postural control and ACL injury risk. However, it should be noted that the short- and long-term reproducibility of the variables selected was poor.

Postural sway, dynamic balance and injury risk

Neither postural sway nor dynamic balance measures in single-leg stabilization differed between players suffering an ACL injury after the baseline screening and uninjured players. Little research exists examining dynamic, functional balance measures or sway velocity in relation to ACL injury risk. Sway velocity reflects the neuromuscular response following a specific movement task; lower sway velocity suggests a superior response to the balance challenge.[25] Consequently, we expected players who went on to suffer an ACL injury to display greater sway velocities in anterior-posterior and medio-lateral directions, covering a larger COP area than those who remained free of injury. Similarly, we expected players with a new ACL injury to perform worse on the SEBT, giving themselves a more unstable stance to reach out far with the contralateral leg.

Thus, our findings seem to be in contrast to those of a recent prospective cohort study with 9 ACL injuries, where DuPrey et al[21] measured time to stabilization for a variety of jump landing tasks in a group of 278 NCAA division I college athletes. They reported a 3-fold increased odds for ACL injury risk with longer stabilization time, albeit following backward jumps only. For comparisons between these to studies, longer time to stabilization likely corresponds to higher average sway velocities.

One potential explanation for the apparent discrepancy between studies could be the nature of the test tasks used, postural sway in single-leg stability and dynamic balance in SEBT. The stabilization challenges to postural control chosen here, may simply be inadequate and not representative for typical handball and football injury situations to produce changes associated with increased ACL injury risk. By asking our players to drop down from a 30 cm high box before stabilizing on two foam pads, we increased the challenge considerably, and both the speed and excursion of the COP increased significantly compared to the purely static task. However, even this more dynamic and challenging task did not discriminate between injured and uninjured players.

We also measured dynamic functional balance with the simplified version of the SEBT, using 3 test directions slightly different from what is commonly used in the literature.[23] With the exclusion of the posterolateral test arm, where the reaching leg crosses behind the player, the simplified version of the SEBT maybe less challenging. Still, we do not believe this difference in test procedures is less likely to detect an association with the outcome measure, ACL injury risk.

In both sports, players jump, land and change direction at high speed while focusing on teammates and opponents. Hence, more sport-specific cutting and jump-landing tasks in combination with single-leg stabilization could have increased the validity of our test, however, also lessening the standardization of the test procedures.

Injury history and injury risk

The consistent identification of previous injury as a risk factor for a subsequent new injury highlights the importance of avoiding the first injury. In the current study, the odds for sustaining a new ACL injury in the group of players with an ACL injury history were tripled, which is in line with other studies on different athlete groups.[26-28] Since the injured group was also highly biased by ACL injury (12 of 55 players), we repeated all analyses excluding players with a history of previous injury. However, the results remained the same. Postural stability measurements during the single-leg stance may be a useful predictor of increased risk of non-contact lower extremity injury.[29] Surprisingly, we could not identify any association between a history of ankle injury the preceding year and ACL injury risk.

Methodological considerations

When interpreting the findings of the present study there are several strengths and limitations that should be kept in mind. With almost 900 female elite athletes tested, this is among the largest prospective studies assessing risk factors for ACL injury. Nevertheless, with our homogenous sample of elite level athletes, the generalizability to other populations, e.g. younger or less fit athletes, is unknown.

Also, even with 55 non-contact ACL injuries included, the study is not sufficiently powered to address more than 5 candidate risk factors, including covariates, at a time.[30] As can be seen from simple comparisons between injured versus uninjured legs, and from short- and long-term reproducibility data, it is clear that none of the factors examined have strong associations with injury risk. In other words, increasing sample size further is unlikely to reveal clinically significant factors.

As used in the present study, the most common and reproducible method for quantifying standing balance is based on COP measures.[31-33] COP sway velocity is seen as the most reliable measure.[31] However, test reproducibility in our cohort was poor.

As with all prospective cohort studies, risk factors may have changed after inclusion. The time between baseline balance testing and the main outcome measure, ACL injury, was on average 1.8 years (range: 1 to 89 months). We do not have follow-up information on player exposure to elite level play, injury history other than new ACL injuries, injury prevention training or other neuromuscular training habits. These are among factors that could influence postural control characteristics, causing misclassification and thus reducing our ability to detect associations with ACL injury risk. Also, short- and long-term test-retest data on our postural control measures showed significant improvements despite of large individual variations, implying a learning effect, as late as after 2 years as after a few weeks following the first test session. Large MDC-values lesson our ability to detect injury risk factors.

Finally, we relied on interviews with the athlete and medical staff to classify injuries as contact, indirect contact or non-contact. Separate regression analyses with all 67 prospective contact and non-contact ACL injuries included, revealed no changes in either postural control, knee motion control[22] or peak strength outcomes measures[34], documenting that potential misclassification of the mechanism of injury is not likely to change the results of this study.

Implications

Several meta-analyses on the effect of multicomponent exercise prevention programs highlight the role of varying neuromuscular training and balance components to be of importance for effective ACL injury risk reduction.[35,36] However, we found no significant difference in either sway velocity, excursion or dynamic balance between injured and uninjured female elite athletes. The selected single-leg stabilization tests may not have been challenging enough to identify players at risk.

Injury risk among highly compliant female elite handball players was effectively reduced when following a one-season ACL injury prevention program that almost solely focused on cut and landing technique, and balance training with knee control.[15] In a separate intervention study using the same exercise protocol, elite football and handball players increased muscle activation of the medial hamstring muscles prior to landing.[37] In other words, there may be other benefits of neuromuscular training than simply improving postural control.

In the present prospective cohort of Norwegian female handball and football players, neither isolated motion patterns during drop jump-landings[22] nor lower extremity strength[34] seem to play a role in ACL injury causation. Hence, combining these neuromuscular variable clusters to address the truly multifactorial nature of ACL injures will not help us in finding associations between those variables and ACL injury risk in our cohort.

Nevertheless, as we still do not understand the mechanisms underpinning effective exercise ACL injury prevention programs, we highly recommend their continued use, irrespective of player level.[13-16]

Conclusion

None of the postural control measures examined were associated with an increased ACL injury risk among female elite ball sport athletes. Hence, the variables included in the current investigation cannot be used to predict injury risk.

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Conflict of interest

None of the co-authors declare any conflict of interest.

Table 1. Demographics, training and injury history of all players, as well as subgroups of players with (N=55) and without a new/recurrent ACL injury following testing (N=783). Results are presented as mean (SD) and as numbers and proportions.

	All players N=838	Players with new/recurrent ACL N=55	Uninjured players N=783	P-value
Age (yrs)	21.0 (4.0)	20.4 (3.5)	21.0 (4.0)	.27
Height (cm)	169.6 (6.4)	170.8 (7.1)	169.5 (6.3)	.32
Body mass (kg)	66.3 (8.0)	67.6 (8.5)	66.2 (7.9)	.20
BMI (kg/m²)	23.0 (2.1)	23.2 (2.0)	23.0 (2.1)	.44
Age when starting elite level play (yrs)	18.3 (2.8)	17.9 (2.8)	18.3 (2.8)	.31
Seasons at elite level (#)	2.5 (3.3)	2.5 (2.9)	2.5 (3.3)	.92
In-season training (h/wk)	9.8 (2.3)	9.4 (1.6)	9.8 (2.4)	.18
Off-season training (h/wk)	8.6 (3.5)	8.8 (3.2)	8.5 (3.5)	.62
Previous ACL injury (#)*	81 (10.0)	12 (22.2)	69 (8.5)	.007
Ankle injury previous year (#)*	377 (45.0)	23 (41.8)	354 (45.2)	.46

*Information missing for 24 players (ACL injury history) and 119 players (ankle injury history). Proportions are presented as valid percentages.

Table 2: Normalized postural control for injured and contralateral non-injured leg among players with a new/recurrent ACL injury (N=55). Between-leg differences are presented as Δ, mean ± 95% CI. Positive values (Δ) denote worse (balance platform) and better (Star Excursion Balance Test) normalized balance scores in the injured leg. Data are shown as means with standard deviations (SD).

	ACL injured legs N=55	Uninjured legs N=55	Δ 95% CI	P
Balance platform test (static)*				
Medio-lateral speed (ML)	0.12 (0.03)	0.12 (0.04)	0 (-0.008; 0.005)	.66
Anterior-posterior speed (AP)	0.14 (0.04)	0.14 (0.04)	0 (-0.007; 0.004)	.67
95% percentile areal	4.7 (1.6)	4.8 (1.9)	-0.1 (-0.5; 0.4)	.81
Balance platform test (drop down)*				
Medio-lateral speed (ML)	0.25 (0.09)	0.25 (0.09)	0 (-0.050; 0.056)	.88
Anterior-posterior speed (AP)	0.42 (0.20)	0.38 (0.09)	0.04 (-0.053; 0.132)	.38
95% percentile areal	16.9 (8.0)	16.6 (7.9)	0.3 (-3.6; 4.2)	.88
Star Excursion Balance Test*				
Anteromedial	0.84 (0.08)	0.83 (0.08)	0.01 (-0.004; 0.021)	.18
Medial	0.86 (0.08)	0.86 (0.08)	0.01 (-0.003; 0.021)	.14
Posteromedial	0.94 (0.08)	0.93 (0.08)	0.01 (-0.001; 0.024)	.06
Composite score	0.87 (0.07)	0.85 (0.08)	0.01 (-0.001; 0.020)	.07

*Data were normalized for player height (Good Balance) or leg-length (Star Excursion Balance Test).

Table 3. Normalized postural control with mean (SD). Differences between injured and uninjured legs are presented for the total cohort, as well as for handball and football players separately, adjusted for dependencies between legs. Data are shown as means with standard deviations (SD).

	All players			Handball players			Football players		
	ACL injured legs	ACL uninjured legs	P	ACL injured legs	ACL uninjured legs	P	ACL injured legs	ACL uninjured legs	P
Balance platform test (static)*	N=44	N=1440		N=20	N=698		N=24	N=742	
Speed ML ((mm/s)/cm)	0.12 (0.03)	0.12 (0.05)	.76	0.13 (0.04)	0.13 (0.04)	.92	0.11 (0.03)	0.12 (0.05)	.63
Speed AP ((mm/s)/cm)	0.14 (0.03)	0.14 (0.04)	.94	0.15 (0.04)	0.14 (0.04)	.49	0.13 (0.02)	0.13 (0.05)	.45
95% percentile areal ((mm^2)/cm)	4.6 (1.4)	4.8 (1.7)	.38	5.0 (1.6)	5.0 (1.8)	.93	4.3 (1.1)	4.6 (1.6)	.20
Balance platform test (drop down)*	N=18	N=633		N=9	N=252		N=9	N=381	
Speed ML ((mm/s)/cm)	0.25 (0.10)	0.25 (0.08)	.70	0.30 (0.10)	0.25 (0.08)	.14	0.21 (0.08)	0.24 (0.08)	.24
Speed AP ((mm/s)/cm)	0.43 (0.21)	0.39 (0.15)	.48	0.45 (0.19)	0.39 (0.15)	.34	0.41 (0.24)	0.39 (0.15)	.88
95% percentile areal ((mm^2)/cm)	17.0 (8.3)	16.2 (10.1)	.70	17.1 (7.9)	16.8 (13.0)	.92	16.9 (9.2)	15.8 (7.6)	.72
Star Excursion Balance Test*	N=55	N=1517		N=25	N=747		N=30	N=770	
Anteromedial (cm/cm)	0.83 (0.07)	0.84 (0.06)	.38	0.86 (0.08)	0.86 (0.07)	.81	0.81 (0.06)	0.83 (0.06)	.11
Medial (cm/cm)	0.87 (0.08)	0.87 (0.07)	.42	0.89 (0.08)	0.89 (0.07)	.89	0.84 (0.07)	0.86 (0.06)	.22
Posteromedial (cm/cm)	0.94 (0.08)	0.95 (0.07)	.25	0.97 (0.08)	0.96 (0.08)	.77	0.92 (0.07)	0.94 (0.06)	.06
Composite score	0.88 (0.07)	0.89 (0.06)	.32	0.91 (0.08)	0.90 (0.07)	.82	0.86 (0.07)	0.88 (0.06)	.10

*Data were normalized for player height (Good Balance) or leg-length (Star Excursion Balance Test).

Table 4: Long-term (1 to 5 yrs) stability of static and dynamic postural control for 144 players (right (R) and left (L) leg). Data are presented as the session 1 baseline value (mean and standard deviation, SD), the mean session difference (with 95% CI), the standard error of measurement (SEM) and the minimal detectable change (MDC). For the Good Balance test negative values denote an improvement from session 1 to session 2, while for the Star Excursion Balance Test positive values represent an improved test score.

	Session 1 baseline		Session difference					MDC
	Mean	SD	Mean	%	95% CI	SEM	%	
Balance platform test (static)*								
R speed ML (mm/s)	22.2	6.7	-3.1	14.0	-4.0, -2.1	3.7	16.7	10.2
R speed AP (mm/s)	23.3	5.3	-1.1	4.7	-2.0, -0.3	3.3	14.2	9.1
R 95% percentile areal (mm²)	791.3	260.5	-7.0	0.9	-54.2, 40.2	187.8	23.7	735.7
L speed ML (mm/s)	21.7	6.6	-2.7	12.4	-3.6, -1.8	3.7	17.1	10.2
L speed AP (mm/s)	23.2	5.6	-1.7	7.3	-2.4, -0.9	0.6	2.6	1.7
L 95% percentile areal (mm²)	790.2	249.6	-44.7	5.6	-88.5, -0.9	173.9	22.0	482.0
Star Excursion Balance Test								
R Anteromedial (cm)	74.1	5.8	2.6	3.5	1.9, 3.4	3.2	4.3	8.9
R Medial (cm)	77.0	6.0	3.3	4.3	2.7, 4.0	2.8	3.6	7.8
R Posteromedial (cm)	84.0	6.2	3.5	4.2	2.7, 4.2	3.0	3.6	8.3
L Anteromedial (cm)	74.2	5.4	2.8	3.8	2.1, 3.6	3.0	4.0	8.3
L Medial (cm)	77.4	6.1	2.9	3.7	2.1, 3.8	3.6	4.7	10.0
L Posteromedial (cm)	84.7	6.1	2.6	3.1	1.6, 3.5	3.8	4.5	10.5

Table 5: Short-term (1 to 7 weeks) stability of static and dynamic postural control for 144 players (right (R) and left (L) leg). Data are presented as the session 1 baseline value (mean and standard deviation, SD), the mean session difference (with 95% CI), the standard error of measurement (SEM) and the minimal detectable change (MDC). For the Good Balance test negative values denote an improvement from session 1 to session 2, while for the Star Excursion Balance Test positive values represent an improved test score.

	Session 1 baseline		Session difference					MDC
	Mean	SD	Mean	%	95% CI	SEM	%	
Balance platform test (static)*								
R speed ML (mm/s)	20.1	6.0	-1.7	8.5	-3.7, 0.4	3.9	19.4	10.8
R speed AP (mm/s)	21.9	5.9	-3.2	14.6	-5.2, -1.2	3.8	17.4	10.5
R 95% percentile areal (mm^2)	886.4	268.6	-93.8	10.6	-204.0, 16.3	208.6	23.5	577.8
L speed ML (mm/s)	18.7	5.7	-1.4	7.5	-3.7, 1.0	4.4	23.5	12.2
L speed AP (mm/s)	21.0	6.4	-2.2	10.5	-4.6, 0.3	4.7	22.4	13.0
L 95% percentile areal (mm^2)	822.6	231.9	-89.8	10.9	-182.6, 2.9	175.6	21.3	486.4
Star Excursion Balance Test								
R Anteromedial (cm)	77.7	6.2	2.3	3.0	2.3 (1.3, 3.3)	2.3	3.0	6.4
R Medial (cm)	80.5	5.6	2.3	2.9	2.3 (1.4, 3.3)	3.3	4.1	6.1
R Posteromedial (cm)	86.7	5.2	1.8	2.1	1.8 (0.6, 2.9)	3.6	4.2	7.2
L Anteromedial (cm)	78.1	6.2	1.7	2.2	1.7 (0.5, 2.9)	2.8	3.6	7.8
L Medial (cm)	81.7	5.3	1.4	1.7	1.4 (0.2, 2.6)	2.8	3.4	7.8
L Posteromedial (cm)	87.1	5.0	2.2	2.5	2.2 (1.1, 3.4)	2.7	3.1	7.5