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The side hop test: Validity, reliability, and quality aspects in relation to sex, age and anterior cruciate ligament reconstruction, in soccer players

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ABSTRACT

Objective: To study the side hop test regarding validity, reliability, and quality in relation to sex, age and ACL-reconstruction in soccer players.
Design: Cohort study.
Participants: 117 females with a primary ACL-reconstruction, and 119 females, 46 males (age 16–26 years), 49 girls and 66 boys (age 13–16 years) without injury.
Main outcome measures: For convergent validity, one physiotherapist analysed side hops live and later on video. One physiotherapist and two physiotherapy students analysed side hops from 92 players for interrater reliability (video). For intrarater reliability, side hops from 35 players were analysed twice (video). Quality aspects (flaws), i.e. number of times the hopping limb touched the strips, the non-hopping limb touched the floor, and double hops/foot turns with the hopping limb, were registered (video).
Results: Convergent validity was excellent; the intraclass correlation coefficient (ICC) was 0.93–1.0. All reliability measures were excellent (ICC 0.92–1.0). Adult male players had fewest and girls had most flaws, especially double hops/foot turns with the hopping limb, compared with all other players (mean, 11–12 vs 1–6, $\eta^2 = 0.18$, large effect size). No differences were reported between knee-healthy and ACL-reconstructed females.
Conclusion: The side hop test is valid and reliable. Quality aspects differ between sexes and ages.

1. Introduction

One-leg hop tests are commonly used to evaluate functional performance and the limb symmetry index (LSI) in athletes with and without injuries in a lower extremity. The side hop test involves the patient hopping on one leg from side to side outside two parallel strips of tape (40 cm apart) aiming to perform as many hops as possible for 30 s. It is complex to perform and incorporates different aspects, including endurance, muscle strength and stability (Gustavsson et al., 2006; Markström, Tengman, & Häger, 2021). There are conflicting results as to whether the side hop test discriminates hop performance between the injured and the uninjured limb in patients who have undergone anterior cruciate ligament (ACL) reconstruction (ACLR) (Gustavsson et al., 2006; Urhausen et al., 2022). It is important that tests used in research and in the clinic have good validity and reliability. In the clinic, the number of hops is usually counted live without video recording, which could be difficult in practice where the test leader needs to keep track of fast hops and only count valid hops where the athlete is not touching the strips. The accuracy of counting live compared with video is not clear; video allows multiple reviews and slow-motion analysis. The side hop test has previously been evaluated regarding reliability but not validity (live vs video). Furthermore, reliability of the side hop test was previously evaluated using a

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different set-up of the side hop test (side hop measuring time on 10 side hops and with the strips 30 cm apart) (Kamonseki, Cedin, Tavares-Preto, & Calixtre, 2018) and evaluation of test-retest reliability (performing the side hop test on three separate occasions) (Gustavsson et al., 2006).

Hop tests are often used to measure quantity, i.e. hop length or number of valid hops. In the side hop test, important movement patterns potentially related to ACL injury risk, such as between-leg asymmetry for peak knee flexion moment, flight time, vertical impact force, jump distance and contact time, have been evaluated using force plates and three-dimensional motion capture systems (Markström et al., 2021; Urhausen et al., 2022). It is recommended to use different hop tests because variations in peak forces exist in both controls and patients with ACLR (Urhausen et al., 2022). In the side hop test, some quality aspects (flaws) can be evaluated visually in the clinic without expensive apparatus, such as the number of times the hopping limb touches the strips, the non-hopping limb touches the floor, and double hops/foot turns with the hopping limb. Identifying differences in quality aspects may provide a broader picture of functional performance and recovery after injury. For example, jumping quickly will result in many hops, but may reduce the dynamic stability and lead to more invalid hops, and jumping slowly may indicate neuromuscular control deficits. Quality aspects of the side hop test, including sex and age differences and having undergone ACLR, have not previously been systematically assessed or evaluated for measurement properties.

Therefore, the purpose of this study was to investigate the side hop test regarding (1) the convergent validity of counting hops live compared with video, (2) interrater and (3) intrarater reliability of video analysis, (4) qualitative aspects in relation to sex and age, and ACLR, and (5) correlation between valid hops and quality aspects.

2. Methods

2.1. Participants and recruitment

A total of 397 soccer players were included in the study and divided into five groups: (1) adult females with ACLR (n = 117), (2) adult knee-healthy females (n = 119), and (3) adult males (n = 46) aged 16–26 years, and knee-healthy (4) girls (n = 49) and (5) boys (n = 66) aged 13–16 years (Fig. 1). Adult females with primary ACLR were enrolled at a mean 19 ± 9 months after ACLR, participating fully in soccer training with the team, at any playing level, and 98% were reconstructed with a hamstring tendon autograft. The participants in this study have been reported and described previously (Arundale, Kvist, Hägglund, & Fältström, 2020; Fältström, Hägglund, Hedevik, & Kvist, 2021; Fältström, Kvist, Bittencourt, Mendonca, & Hägglund, 2021; Fältström, Kvist, Gauffin, & Hägglund, 2019; Sonesson et al., 2022; Sonesson, Lindblom, & Hägglund, 2021). The players received written and oral information about the study and signed written informed consent before testing. All the youth players plus their guardians provided their written informed consent before participation.

2.2. Test procedure

The test procedure has been described in detail in previous studies (Arundale et al., 2020; Fältström et al., 2019; Lindblom, Waldén, Carlfjord, & Hägglund, 2020; Lindblom, Waldén, & Hägglund, 2020). The players wore their own indoor shoes and clothing during testing. Players performed a standardized warm-up before performing a battery of tests included in the previous studies. Only the results of the side hop test are presented here. A few test hops were performed on each limb before the test trial. The test trials were performed using the uninvolved limb first for the females with ACLR and the right limb for the other players (dominant [preferred kicking limb] for 97% of the females and 93% of the males; not collected for the girls and boys). The players hopped from side to side on one limb outside two parallel strips of tape 40 cm apart. Hands were placed behind their back. Players were instructed to hop as many hops as possible for 30 s. The players had to rest for at least 1 min before testing the opposite limb. The trials were videotaped with a camera positioned in the frontal plane (Panasonic HC-V500M video camera with frame rate 50 frames per second for the females, Sony HDR-CX260 video camera with frame rate 50 frames per second for the males, and GoPro Hero5 video camera with frame rate 60 frames per second for the youth players).

2.3. Evaluation of the side hop test

Side hops not touching the strips were counted as valid (Gustavsson et al., 2006). The LSI was calculated for the valid hops ([ACLR limb/uninvolved limb] × 100 for players with ACLR, [nondominant limb/dominant limb] × 100 for the knee-healthy female and male players, [left limb/right limb] × 100 for the youth players). The following quality aspects (flaws) were evaluated during the video analysis: (1) number of times the hopping

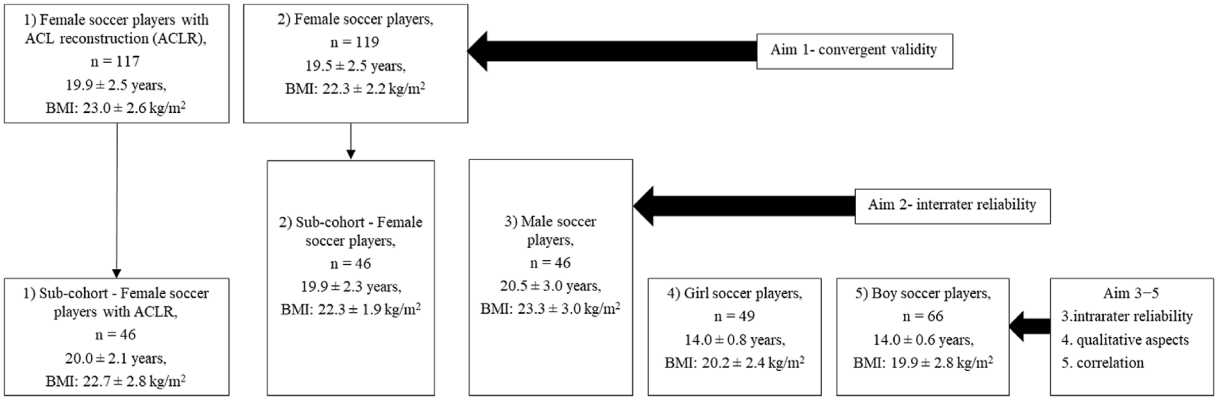

Fig. 1. Participant flow diagram.
The five different cohorts: (1) females with anterior cruciate ligament (ACL) reconstruction (ACLR), (2) knee-healthy females recruited from the same teams as the female players with ACLR, (3) knee-healthy males matched regarding age (16–25 years), playing position and playing level to the knee-healthy female soccer players, (4) girls and (5) boys aged 13–16 years from 8 youth teams. BMI, body mass index.

limb touched the strips, (2) number of times the non-hopping limb touched the floor, and (3) double hops/foot turns with the hopping limb. The validity and reliability were calculated and reported both for the ACLR limb and the uninvolved limb (group 1) and for the dominant and nondominant limb (group 2).

2.3.1. Convergent validity: counting live compared with video

One physiotherapist with more than 25 years of clinical experience (A.F.) counted live the total number of hops and the quality aspect "times the hopping limb touched the strips", for all the females (groups 1 and 2) during the side hop tests on both limbs. Valid hops, i.e. total hops minus hops when the hopping limb touched the strips, and the LSI were calculated afterwards. After about 1 year, the same physiotherapist analysed all the side hop tests again by watching the films as many times as needed, first at normal speed and then in slow motion using Windows Movie Maker, version 2012 (Microsoft Corp., Redmond, WA). Whether the players had an ACLR or not and which limb was dominant or reconstructed could not be identified on the films.

2.3.2. Interrater reliability of video analysis

To test the interrater reliability, the experienced physiotherapist (A.F.) and two physiotherapy students counted valid hops and analysed quality aspects by reviewing the films for both limbs of 92 knee-healthy players (groups 2 and 3) (Fig. 1). The two physiotherapy students were instructed and trained before reviewing the videos. Due to practical and time constraints, no films from groups 1, 4 and 5 were analysed.

2.3.3. Intrarater reliability of video analysis

Intrarater reliability was tested by the experienced physiotherapist (A.F.) counting valid hops and analysing quality aspects of both limbs for 35 players randomly selected from the total cohort (groups 1–5). The films were analysed at least 5 days apart.

2.3.4. Quality aspects of the side hop test in relation to sex, age and ACLR

Players from all cohorts (46 players from groups 1 and 2, and 3–5) were included to study quality aspects of the side hop test and if there were sex and age differences (Fig. 1). The results from the first video analysis by the physiotherapist (A.F.) were used for the comparisons.

2.3.5. Correlation between valid hops and quality aspects

The correlation between valid hops and quality aspects was evaluated from the same cohorts as in aim 4 (46 players from groups 1 and 2, and 3–5) (Fig. 1).

2.4. Statistical analyses

All statistical analyses were performed with SPSS Statistics for Windows (v 27.0; IBM Corp; Armonk, NY). Means ± standard deviation (SD) were calculated for descriptive statistics. Intraclass correlation coefficients (ICCs) from repeated measures of analysis of variance (ANOVA), a two-way random model with absolute agreement, single measure, was used to analyse the side hop test live compared with video (convergent validity), and inter- and intrarater reliability. ICC values, measures of relative validity and reliability, were classified as excellent (>0.90), good (0.75–0.89), moderate (0.50–0.74), or poor (<0.50). The standard error of measurement (SEM) was calculated as $SD \times \sqrt{(1 - ICC)}$ and the results are illustrated in plot diagrams according to Bland and Altman to support the reader to interpret the results. Between-group comparisons of the five groups of soccer players (females with or without ACLR, males, girls and boys) regarding quality aspects, valid hops and the LSI in the side hop test were made with one-way ANOVA with Tukey's b post hoc test. Effect sizes are presented as eta squared (η^2): $\eta^2 = 0.01$ indicates a small effect; $\eta^2 = 0.06$ a medium effect; $\eta^2 = 0.14$ a large effect. The level of significance was set at $P \leq 0.05$. Pearson's correlation coefficient was calculated to determine the strength of correlation between valid hops and the quality aspects. The strength of correlation coefficients was interpreted as negligible at ≤0.30, weak at 0.31–0.50, moderate at 0.51–0.70, or strong at >0.71.

3. Results

3.1. Convergent validity: counting live compared with video

The convergent validity for valid hops, the LSI and the quality aspect "number of times the hopping limb touched the strips", was excellent and the ICC ranged from 0.93 to 1.0, with SEM 1 for valid hops and 4.0%–4.2% for the LSI (Bland-Altman plots are shown in the Supplementary material) (Table 1). Fig. 2 shows the differences in LSI between counting live vs video. Nine percent of the side hop tests differed more than 10% in the LSI when comparing live versus video (Fig. 2).

3.2. Interrater reliability of video analysis

The interrater reliability for valid hops, the LSI and quality aspects in the side hop test was excellent and the ICC ranged from 0.92 to 1.0 with SEM 1 for valid hops and 3.9% for the LSI (Table 2). The results are illustrated in Bland-Altman plots in the Supplementary material.

3.3. Intrarater reliability of video analysis

The intrarater reliability for valid hops, the LSI and quality aspects was excellent and the ICC was 0.97 (95% CI, 0.94–1.0) with SEM 0.5 for valid hops and 1.9% for the LSI (Table 2). Results are illustrated in Bland-Altman plots in the Supplementary material.

3.4. Quality aspects of the side hop test in relation to sex, age and ACLR

Youth players, and especially girls, touched the floor with the non-hopping limb more often than adult females and males (mean 1–2 times versus 0 times). Double hops/foot turns with the hopping limb occurred most in girls (mean, 11–12) and least in adult males (mean 1) compared with the other groups. All differences had large effect sizes ($\eta^2 = 0.14$–0.23). The LSI did not differ between the groups. None of the variables differed between females with or without ACLR (Table 3).

3.5. Correlation between valid hops and the quality aspects

The number of valid hops was negatively correlated with the number of times the non-hopping limb touched the floor ($r = -0.27$ to -0.34, $P < 0.001$) and the number of double hops/foot turns with the hopping limb ($r = -0.50$ to -0.57, $P < 0.001$), but no correlation was seen between the number of times the hopping limb touched the strips for the dominant and nondominant limbs ($r = -0.07$ to -0.08, $P = 0.260$ and 0.270). Thus, hop techniques with a higher number of times the non-hopping limb touched the floor and more double hops/foot turns were associated with less valid hops.

4. Discussion

The main findings of the present study were that the convergent

Table 1
The convergent validity of the side hop test live compared with video in adult female soccer players with (n = 117) or without (n = 119) primary anterior cruciate ligament (ACL) reconstruction (ACLR)[a].

	All adult female soccer players, n = 236				ACLR, Group 1, n = 117				Females, Group 2, n = 119			
	Live	Video	ICC (95% CI)	SEM	Live	Video	ICC (95% CI)	SEM	Live	Video	ICC(95% CI)	SEM
Uninvolved limb, dominant limb for the knee-healthy females												
Valid hops, n	38 ± 13 (11–70)	38 ± 13 (11–71)	1.0 (0.99–1.0)	1.0	37 ± 13 (11–70)	37 ± 14 (11–71)	1.0 (0.99–1.0)	1.0	39 ± 13 (15–70)	39 ± 13 (15–70)	0.99 (0.99–1.0)	1.0
Number of times the hopping limb touched the strips, n	4 ± 4 (0–20)	5 ± 4 (0–22)	0.93 (0.91–0.95)	0.9	4 ± 4 (0–17)	5 ± 4 (0–19)	0.93 (0.90–0.95)	0.9	4 ± 3 (0–20)	5 ± 4 (0–22)	0.93 (0.90–0.95)	0.9
ACLR limb, nondominant limb for the knee-healthy females												
Valid hops ACLR limb, n[b]	36 ± 14 (7–71)	36 ± 14 (8–74)	0.99 (0.99–1.0)	1.1	34 ± 14 (8–71)	35 ± 15 (9–74)	0.99 (0.99–1.0)	1.2	38 ± 13 (7–69)	38 ± 14 (8–70)	0.99 (0.99–1.0)	1.0
Number of times the hopping limb touched the strips, n	4 ± 4 (0–21)	5 ± 4 (0–23)	0.95 (0.93–0.96)	0.9	5 ± 4 (0–21)	5 ± 5 (0–23)	0.95 (0.92–0.96)	1.0	4 ± 4 (0–19)	4 ± 4 (0–20)	0.95 (0.93–0.96)	0.9
Limb symmetry index (LSI), %	96 ± 17 (25–139)	96 ± 18 (28–163)	0.96 (0.95–0.98)	4.1	94 ± 19 (25–139)	94 ± 19 (28–139)	0.96 (0.94–0.97)	4.0	97 ± 15 (47–139)	98 ± 17 (42–163)	0.93 (0.90–0.95)	4.2

Abbreviations: ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; ICC, intraclass correlation; SEM, standard error of measurement.
The dominant limb was the preferred kicking limb.
[a] *Data are mean ± SD (range).*
[b] *One player with ACLR did not jump on her ACLR limb and was not included in the analysis.*

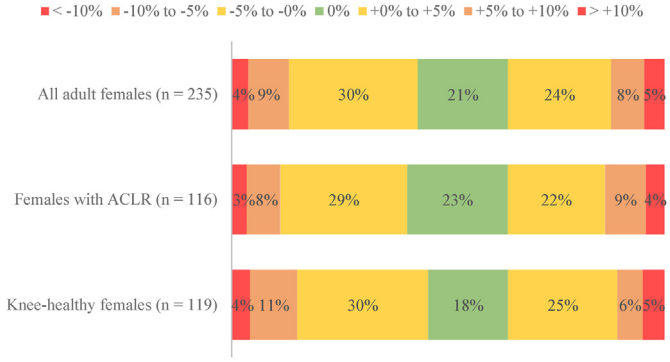

Fig. 2. The difference in the limb symmetry index (LSI) between counting live compared with video in all adult females (n = 235, one missing from females with ACLR) and divided into (1) 116 females with anterior cruciate ligament (ACL) reconstruction (ACLR) and (2) 119 knee-healthy females. Minus and plus indicate that the LSI was lower or higher live compared with video. The percentages in the figure correspond to the proportion of estimates of the LSI in the various categories where the differences were 0%, ±0%–5%, ±5%–10%, and >±10%.

validity of the side hop test live compared with video and the inter- and intrarater reliability of video analysis were classified as excellent regarding all measured variables. Quality aspects differed in terms of different approaches to the side hop test between sexes and ages; males had the most valid hops with less flaws and youth girls had most flaws.

4.1. Convergent validity: counting live compared with video

Analysing the side hop test live compared with video showed an excellent ICC in the number of valid hops, number of times the hopping limb touched the strips, and the LSI. This suggests that an experienced clinician can use the side hop test without video recording with scrutiny after completion. In our study, only total hops and the number of times the hopping limb touched the strips, not the other quality aspects, were analysed live. However, quality aspects may be evaluated to get a broader picture of functional performance and recovery after injury. It has previously been reported that simple screening tests, such as the drop vertical jump (DVJ) evaluating knee valgus angles, can reliably be performed live using only visual assessment and provide a cost- and time-effective screening (Nilstad et al., 2014; Stensrud, Myklebust, Kristianslund, Bahr, & Krosshaug, 2011). However, live assessment of DVJ test scores correlated poorly with knee abduction moments measured with three-dimensional motion analysis (Nilstad et al., 2014). If there are too many aspects to assess and complex movements to screen, video recording is probably needed. We found that 9% of the tests analysed live compared with video differed more than 10% in the LSI depending on differences in valid hops in the compared limbs. The recommended cutoff value for side to side difference is 10% (Gustavsson et al., 2006), meaning that every tenth test could be misinterpreted if video is not used.

4.2. Inter- and intrarater reliability of video analysis

The inter- and intrarater reliability were excellent for valid hops, LSI and quality aspects in the side hop test. The reliability has not been studied previously after video scrutiny and not with quality aspects. However, the interrater ICC for valid hops has previously been reported to range from 0.83 to 0.91 and the intrarater reliability from 0.63 to 0.67 in 10- to 16-year-old healthy boys in the side hop test, but with the two parallel strips 30 cm apart and hopping ten times as fast as possible (Kamonseki et al., 2018). Also previously reported test-retest reliability for the side hop test in three groups (knee-healthy persons, patients with ACL injury or ACLR) performing the side hop test on three separate occasions was excellent (ICC, 0.87–0.93) (Gustavsson et al., 2006). Thus, the results from this and previous studies support the side hop test as a reliable test to evaluate players of different ages and sexes.

4.3. Quality aspects of the side hop test in relation to sex,age and ACLR

Different quality aspects in the side hop test in relation to sex and age have not been reported previously. Male adult players had less flaws than all other groups. Youth players, and especially girls, had most flaws. We have described previously that male players showed better performance on the tuck jump test and better knee control with less valgus in the DVJ test than knee-healthy females (Arundale et al., 2020). In general, male athletes aged 8–18 years outperform female athletes in counter movement jumps, DVJs, and agility, and these sex differences increased with age and maturity (Lesinski et al., 2020). Decreased neuromuscular control with more technique errors measured with the tuck jump test and in single-leg hop performance have been reported previously in younger

Table 2
The interrater and intrarater reliability of the side hop test after video analysis[a].

	Interrater reliability[b]					Intrarater reliability (Rater 1)[c]			
	Rater 1(experienced)	Rater 2	Rater 3	ICC (95% CI)	SEM	Video 1	Video 2	ICC (95% CI)	SEM
Uninvolved limb, dominant limb for the knee-healthy females									
Valid hops, n	45 ± 14 (18–70)	45 ± 14 (18–70)	44 ± 14 (18–69)	0.99 (0.99–1.0)	1.1	40 ± 14 (18–70)	40 ± 14 (18–70)	1.0 (1.0–1.0)	0.5
Number of times the hopping limb touched the strips, n	5 ± 5 (0–23)	5 ± 5 (0–21)	5 ± 5 (0–21)	0.98 (0.98–0.99)	0.6	5 ± 4 (0–14)	5 ± 4 (0–15)	0.98 (0.97–0.99)	0.5
Number of times the non-hopping limb touched the floor, n (%)	0 ± 1 (0–3)	0 ± 1 (0–3)	0 ± 1 (0–3)	0.92 (0.88–0.94)	0.2	0 ± 1 (0–3)	0 ± 1 (0–4)	0.97 (0.94–0.98)	0.2
0 times	69 (75)	70 (76)	72 (78)			27 (77)	27 (77)		
1–2 times	19 (21)	21 (23)	19 (21)			5 (14)	6 (17)		
≥3 times	4 (4)	1 (1)	1 (1)			3 (9)	2 (6)		
Double hops/foot turns, n	2 ± 5 (0–36)	2 ± 5 (0–36)	2 ± 5 (0–36)	0.97 (0.95–0.98)	1.0	5 ± 9 (0–36)	5 ± 9 (0–36)	0.99 (0.98–1.0)	0.9
ACLR limb, nondominant limb for the knee-healthy females									
Valid hops, n	45 ± 16 (11–72)	45 ± 16 (11–72)	45 ± 16 (11–72)	1.0 (1.0–1.0)	0.9	40 ± 15 (18–70)	40 ± 15 (18–69)	1.0 (1.0–1.0)	0.4
Number of times the hopping limb touched the strips, n	5 ± 5 (0–25)	4 ± 5 (0–25)	5 ± 5 (0–26)	0.97 (0.96–0.98)	0.9	5 ± 4 (0–15)	5 ± 4 (0–15)	1.0 (0.98–1.0)	0.4
Number of times the non-hopping limb touched the floor, n (%)	0 ± 1 (0–4)	0 ± 1 (0–4)	0 ± 1 (0–4)	0.91 (0.87–0.93)	0.2	0 ± 1 (0–2)	0 ± 1 (0–2)	0.97 (0.94–0.99)	0.1
0 times	74 (80)	71 (77)	71 (77)			23 (66)	22 (63)		
1–2 times	16 (17)	18 (20)	20 (22)			12 (34)	13 (37)		
≥3 times	2 (2)	3 (3)	1 (1)			0 (0)	0 (0)		
Double hops/foot turns, n	3 ± 6 (0–35)	3 ± 6 (0–35)	3 ± 6 (0–35)	0.96 (0.94–0.97)	1.3	5 ± 9 (0–35)	6 ± 9 (0–36)	0.99 (0.98–1.0)	0.9
Limb symmetry index (LSI), %	101 ± 17 (18–157)	101 ± 17 (19–147)	101 ± 17 (18–171)	0.95 (0.93–0.96)	3.9	100 ± 18 (60–157)	100 ± 19 (66–164)	1.0 (1.0–1.0)	1.9

Abbreviations: ACLR, anterior cruciate ligament reconstruction; ICC, intraclass correlation; SEM, standard error of measurement. The dominant limb was the preferred kicking limb.

[a] *Data are mean ± SD (range).*

[b] *for 46 knee-healthy female and 46 male soccer players.*

[c] *for 35 players randomly chosen from the total cohort of female soccer players with or without ACL reconstruction, males, girls and boys soccer players.*

ages (Arundale et al., 2020; Read, Oliver, De Ste; Croix, Myer, & Lloyd, 2018; Read, Oliver, Myer, et al., 2018; Sonesson et al., 2022). It is not clear if the different hop approaches and the quality aspects in the side hop test are a result of neuromuscular control deficits. Hopping with more flaws in the side hop test could be due to fear or reduced strength, balance or low general fitness.

None of the quality aspects or performance in the side hop test differed between females with or without ACLR. Similarly, a previous study found that contact time, flight time, number of hops, and hop distance in the side hop test were not affected in patients 9 months after ACLR compared with controls (Urhausen et al., 2022). To our knowledge, other aspects in addition to valid hops in the side hop test have only been investigated with force plates previously (Markström et al., 2021; Urhausen et al., 2022). The correlation between valid hops and quality aspects was negligible to moderate. Therefore, assessing quality aspects only using a video camera/mobile phone may be a complement to counting the number of valid hops because they seem to measure different aspects of hop performance. However, further evaluation of whether these quality aspects, and sex and age differences, are important regarding soccer performance or future risk for injury is needed.

4.4. Strengths and limitations

Some strengths with our study were the large cohort of soccer players of different sexes and ages, and a standardized test procedure including identical instructions for all players.

There are several limitations in this study. The side hop test was only analysed live for the female players with or without ACLR, and the interrater reliability was only measured in knee-healthy females and males. Ideally, the convergent validity and interrater reliability should have included players from all groups. However, the intrarater reliability was excellent including players from all groups. The distribution of players into cohorts was based on data collection and not on chronological age or maturation, and four players in the adult groups (two females and two males) overlapped the youth players' chronological upper age range of 16 years. We kept the cohorts as included originally because of the matching of the females with and without ACLR and the males regarding playing position, training exposure and age. The girls and boys were included from different youth teams with different ages. There was only a single experienced rater (A.F.) for live analysis, which is a strength when investigating convergent validity, but no testing of interrater reliability was performed live. Thus, we cannot say whether the results are valid for unexperienced raters. The cohorts were filmed with different cameras with frame rates between 50 and 60 frames/s, but all videos were of high quality and this should have minimal impact on the analysis process. Another limitation was a lack of knowledge of the dominant limb for the youth players, and therefore the most common limb for dominance (right) was used (dominant limb for 93–97% of the other players) in comparisons. The side hop test can be performed many different ways with different distances between the strips and different hopping times (Markström et al., 2021; Mirković et al., 2022; Ortiz, Olson, Trudelle-Jackson, Rosario, & Venegas, 2011). Whether the results are valid for ways of performing the tests other than as stated in the current study is unclear.

5. Conclusions

The side hop test is a valid and reliable test that can be used in

Table 3
Valid hops and quality aspects in the side hop test in adult female soccer players with or without anterior cruciate ligament reconstruction, adult males, girl and boy soccer players[a].

	ACLR	Knee-healthy				*P* value	Tukey-b post hoc test		Eta squared ($\eta 2$)
	Females: Group 1, n = 46	Females: Group 2, n = 46	Males: Group 3, n = 46	Girls: Group 4, n = 49[b]	Boys: Group 5, n = 66[c]		Group 1–5		
Uninvolved limb, dominant limb for the knee-healthy females									
Valid hops, n	37 ± 14 (11–68)	38 ± 13 (18–70)	52 ± 12 (21–69)	33 ± 11 (8–57)	42 ± 11 (13–66)	**<0.001**	**3 vs 1,2,4,5**	**5 vs 4**	**0.21**
Number of times the hopping limb touched the strips, n	5 ± 5 (0–14)	5 ± 4 (0–22)	6 ± 6 (0–23)	7 ± 6 (0–23)	7 ± 46 (0–30)	0.258			0.02
Number of times the non-hopping limb touched the floor, n (%)	0 ± 1 (0–3)	0 ± 1 (0–3)	0 ± 1 (0–2)	2 ± 1 (0–5)	1 ± 1 (0–5)	**<0.001**	**4 and 5 vs 1,2,3**		**0.15**
0 times	24 (52)	36 (78)	38 (83)	13 (28)	36 (56)				
1–2 times	20 (44)	8 (17)	8 (17)	25 (53)	23 (36)				
≥3 times	2 (4)	2 (4)	0 (0)	9 (19)	5 (8)				
Double hops/foot turns, n	4 ± 4 (0–23)	4 ± 7 (0–36)	1 ± 2 (0–10)	11 ± 11 (0–36)	5 ± 5 (0–24)	**<0.001**	**4 vs 1,2,3,5**	**5 vs 3**	**0.18**
ACLR limb, nondominant limb for the knee-healthy females									
Valid hops, n	35 ± 15 (9–65)	37 ± 14 (15–64)	53 ± 13 (11–72)	32 ± 11 (8–58)	40 ± 13 (7–67)	**<0.001**	**3 vs 1,2,4,5**	**5 vs 4**	**0.23**
Number of times the hopping limb touched the strips, n	6 ± 5 (0–19)	5 ± 5 (0–19)	5 ± 5 (0–25)	7 ± 6 (0–22)	7 ± 6 (0–26)	**0.026**			0.04
Number of times the non-hopping limb touched the floor, n (%)	1 ± 1 (0–4)	0 ± 1 (0–4)	0 ± 1 (0–2)	1 ± 1 (0–6)	1 ± 1 (0–3)	**<0.001**	**4 vs 1,2,3,5**		**0.14**
0 times	33 (72)	34 (74)	35 (76)	16 (33)	32 (49)				
1–2 times	9 (20)	8 (17)	11 (24)	19 (39)	22 (34)				
≥3 times	4 (9)	4 (8)	0 (0)	14 (29)	11 (17)				
Double hops/foot turns, n	5 ± 6 (0–24)	6 ± 8 (0–35)	1 ± 2 (0–8)	12 ± 12 (0–34)	6 ± 7 (0–28)	**<0.001**	**4 vs 1,2,3,5**	**3 vs 1,2,4,5**	**0.18**
Limb symmetry index (LSI), %	95 ± 18 (28–129)	98 ± 14 (60–130)	104 ± 19 (18–157)	96 ± 18 (57–150)	96 ± 18 (50–148)	0.098			0.03

Abbreviations: ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction. The dominant limb was the preferred kicking limb. Values in bold type are significant.

[a] *Data are mean ± SD and (range) or n (%). Tukey-b post hoc test is used to make pairwise comparisons between groups. $\eta^2 = 0.01$ indicates a small effect; $\eta^2 = 0.06$ a medium effect; $\eta^2 = 0.14$ a large effect.*

[b] *0–2 missing values.*

[c] *1–2 missing values.*

clinical practice without video recording. However, video is probably needed to evaluate the quality aspects. Hop techniques differ between sexes and ages; adult males hopped most hops with less flaws and youth, especially girls, had less hops with more flaws.

Ethical approval

The study was approved by the Swedish Ethical Review Authority (Dnr 2012/24-31, 2013/75-32, 2017/324-32, Dnr 2017/294-31). Players signed a written informed consent form before inclusion.

Data sharing

De-identified data are available from the first author upon reasonable request.

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Declaration of competing interest

The authors affirm that they have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2023.05.008.

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