Using a target as external focus of attention results in a better jump-landing technique in patients after anterior cruciate ligament reconstruction - A cross-over study

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Using a target as external focus of attention results in a better jump-landing technique in patients after anterior cruciate ligament reconstruction – A cross-over study

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ABSTRACT

Background: Improving jump-landing technique during rehabilitation is important and may be achieved through different feedback techniques, i.e., internal focus of attention (IF) or external focus of attention using a target (EF). However, there is a lack of evidence on the most effective feedback technique after anterior cruciate ligament reconstruction (ACLR). The purpose of this study was to investigate the potential difference in jump-landing techniques between IF and EF instructions in patients after ACLR.
Methods: Thirty patients (12 females, mean age 23.26 ± 4.91 years) participated after ACLR. Patients were randomly assigned into two groups that each followed a different testing sequence. Patients performed a drop vertical jump-landing test after receiving instructions with varying types of focus of attention. The Landing Error Scoring System (LESS) assessed the jump-landing technique.
Results: EF was associated with a significantly better LESS score ($P < 0.001$) compared with IF. Only EF instructions led to improvements in jump-landing technique.
Conclusion: Using a target as EF resulted in a significantly better jump-landing technique than IF in patients after ACLR. This indicates that increased use of EF could or might result in a better treatment outcome during ACLR rehabilitation.

1. Introduction

A rupture of the anterior cruciate ligament (ACL) is a common and devastating lower extremity injury that frequently occurs in high-risk pivoting sports such as handball and football [1–3]. Athletes who wish to resume high-level activities are often advised to undergo an ACL reconstruction (ACLR) [4], and post-surgical rehabilitation to prepare the athlete for returning to sport safely.

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Despite a successful ACLR, only two-thirds of athletes return to the pre-injury level of sport after 1 year [5]. Additionally, it has been estimated that 20% of athletes who return to sports (RTS) will suffer a second ACL injury at some point [6], and the highest incidence is commonly seen within 2 years after ACLR, affecting both the ipsilateral and contralateral leg [7,8]. Several risk factors are of influence for a second ACL injury. Neuromuscular deficits and asymmetrical movement patterns, which often persist for months or even years after surgery, are predictive of a second ACL injury [9]. Neuromuscular deficits and asymmetrical movement patterns might not be optimally targeted within current ACLR rehabilitation programs, which primarily focus on motor performance and motor control by addressing mobility, neuromuscular control, strength, balance, and in the later phase sport-specific movements [10–12].

An important component in the ACLR rehabilitation for reacquiring proper movement technique is an optimized jump-landing technique in jumping sports [9,11,13–15], which might reduce neuromuscular deficits and asymmetrical movement patterns [13]. Recent research has shown that focus of attention might play an important role in improving motor performance and skills [16]. The patient's attention can be guided through either internal or external focus. In internal focus of attention (IF), the patient's attention is directed on how to perform body movements (e.g., "land with your knees flexed"). In external focus of attention (EF), the patient's focus is directed toward the outcome or effects of the movement (e.g., "imagine sitting down on a chair when landing") [11,14,16–18]. A study by Durham et al. has shown that instructions with IF were given in 96% of the time in paraplegic patients [19]. During the past 15 years, more studies have demonstrated the beneficial effects of EF compared with IF as it accelerates learning and enhances the production of efficient movement patterns [14,20,21]. Additionally, providing instructions with EF might allow a patient to pay more attention to other sport-specific game factors (e.g., position of the ball, field conditions, and other extrinsic factors) and as a result, improve the movement quality of the injured leg and reduce the risk of a second ACL injury [14,22]. However, the use of EF has only been investigated verbally in patients after ACLR, even though studies indicate a need for making the EF more sport-specific [14,22], e.g., with the use of a target during a jump-landing technique, as it is highly important to be able to redirect attention to relevant environmental cues [23]. Therefore, the primary purpose of this study was to investigate the potential difference between IF and EF on the jump-landing technique assessed with the LESS in patients after ACLR. It is hypothesized that the use of EF results in a lower LESS score compared with the use of IF. The secondary purpose was to explore the potential difference between IF and EF of the LESS items.

2. Methods

2.1. Participants

Thirty patients were included in the study that was conducted in the outpatient physical therapy facility. Enrolment, allocation, and testing were conducted by two testers who were not blinded (MB and WW). Potential patients were identified from a list obtained by the physical therapy facility. All patients followed the same rehabilitation protocol. If patients were eligible, they were contacted by one of the two testers. Included patients received an information letter about the content and procedure of the research. The inclusion criteria for the patients were in line with a previous clinical trial [15]. They were as follows: (1) age older than 18 years, (2) more than 5 months after ACLR, (3) had either hamstring tendon autograft or bone–patellar-tendon–bone autograft, (4) active in pivoting sports before the injury, and (5) had the ambition to RTS. The exclusion criteria were: (1) swelling of the injured knee (stroke test above 'trace') [24], (2) self-reported instability during jump-landing exercises, and (3) pain during jump-landing exercises. All patients signed an informed consent before testing. Subjects were randomly assigned into two groups that followed a different testing sequence. The allocation sequence for the patients was kept concealed, and they were unaware of which type of instruction was provided during each test. Therefore, the patients were blinded to the study hypothesis. Data collection took place during the period from April 2018 to May 2021.

2.2. Study design

Reporting of the within-subject cross-over study follows relevant CONSORT Guidelines for Randomised Trials of Non-pharmacologic Treatment and Consensus on Exercise Reporting Template [25,26]. The study was approved by the Medical ethical board of the University of Groningen (ECB/2014.1.20_1). Collaborative research was initiated between Aalborg University and one outpatient physical therapy facility in Groningen, the Netherlands.

2.3. Procedure

Patients were required to wear their own sports clothing and indoor shoes during the test session. Before testing, the patients performed a 10-min warm-up on a stationary bike at low intensity. During warm-up, the patients received information about the testing procedure, which included three series of vertical jumps in one of the following sequences: sequence 1, no focus of attention (NF), IF, and EF; or sequence 2, NF, EF, and IF. Each jump series consisted of three jumps with a 30-s rest between each jump. Furthermore, a rest period of 5 min was set between the jump series to prevent fatigue

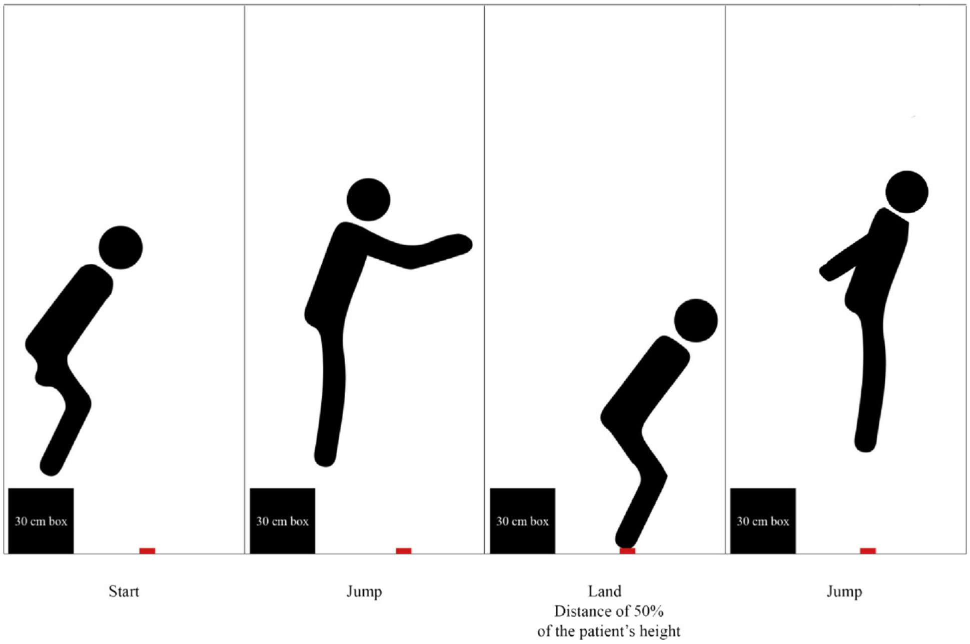

Figure 1. Drop vertical jump with internal focus of attention.

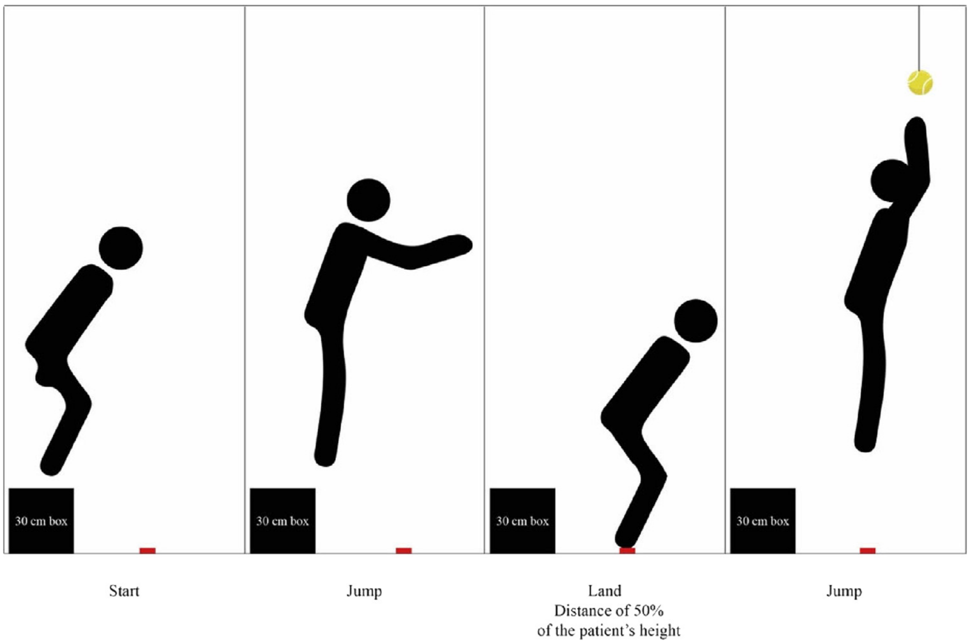

Figure 2. Drop vertical jump with external focus of attention.

[15]. Each jump was performed from a 30-cm box to a squared landing point marked on the ground with tape at a distance of 50% of the patient's height. The drop vertical jump test is demonstrated in Figure 1 with the use of IF and in Figure 2 with the use of EF.

Patients were asked to stand with both feet on the jump box, jump down on to the ground, and immediately perform a vertical jump as high as possible [27]. Patients were allowed to practice the test three to five times. The first jump series was performed to estimate the baseline level with only general instruction, i.e., NF ("jump down from the box into the squared landing point and immediately jump as high as you can"). After the baseline measurements, patients performed the second jump series. The testing sequence that the patients followed in the two groups determined which type of instructions they received for the second and third jump series. Patients in Group A (sequence 1) received IF in the second jump series ("jump down from the box into the squared landing point, extend your knees while jumping up, and flex your knees when landing"). In the third jump series, the patients in Group A received EF ("jump down from the box into the squared landing point and immediately while jumping up, try to hit the tennis ball hanging down from the ceiling"). Patients in Group B (sequence 2) received EF in the second jump series and IF in the third jump series. No further instructions were given besides the general instruction described above to ensure that the conditions provided for the patients were comparable. A target (tennis ball) was suspended before the jump series, which used instructions to create an EF (Figure 2). The position of the tennis ball was adjusted with a total of 80 cm for each patient with respect to the patient's height. This included a standardized anticipated jump height of 40 cm and an additional standardized height of 40 cm between the patient's head and the top of the index finger.

The total testing time, including set-up, was approximately 25 min. A jump was assessed as successful if the patient (1) jumped off with both feet from the box, (2) landed with both feet entirely on the ground, and (3) completed the task in a fluid motion [27].

All tests were digitally recorded by two video cameras (Sony; DCR-hc62, 60 Hz, 40× optical zoom, San Diego, CA, USA) that were placed in sagittal and frontal planes. Other studies have applied a similar video recording tool for capturing jump-landing movements [28–30]. To assess the performance, the frontal plane camera was placed 5 m from the starting point at the jump box, and the sagittal plane camera was placed 1.5 m from the starting point at the jump box. Both camera lenses were set at a height of 1 m above the ground. Within the set-up, the hanging tennis ball could not be seen. The set-up of the experiment is presented in Figure 3. A previous study demonstrated that this set-up and type of video recording is a valid and reliable method (intraclass correlation coefficient (ICC) = 0.91) for identifying potentially high-risk movement patterns during a jump-landing task [27].

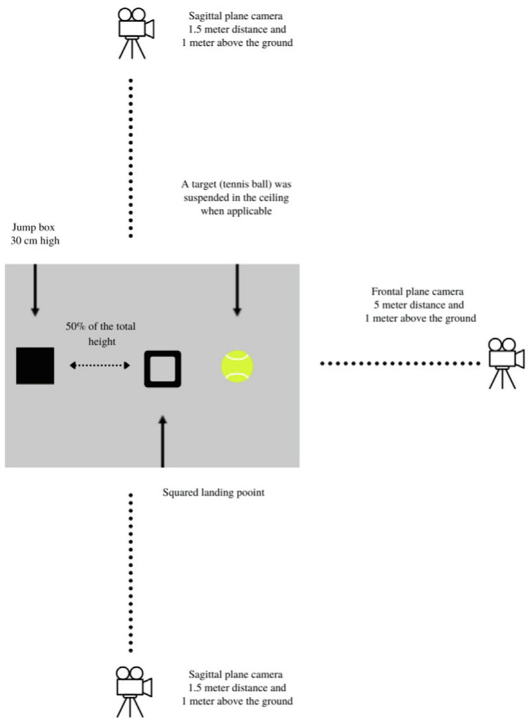

Figure 3. Set-up data collection.

2.4. Measurement tool

The Landing Error Scoring System (LESS) was used to score the jump-landing performance of the patients. It is a clinical assessment tool developed to provide a standardized instrument for detecting the presence of high-risk movement patterns during a jump-landing task [27].

The LESS consists of 17 scoring items and counts the number of landing technique 'errors.' The score of 15 items is either 'yes' or 'no', which will give 0 and 1 point, respectively, and for two items, it is possible to score two points. Thus, the total score will be in the interval from 0 to 19 points and can be divided into excellent (score $\leq$ 4), good (>4 to $\leq$5), moderate (>5 to $\leq$6), and poor (score > 6). A higher LESS score indicates a poorer jump-landing technique, while a lower LESS score indicates a better jump-landing technique [27]. The item definition and scoring of the LESS are presented in the Supplementary material (Appendix I). The minimal detectable change ranges from 0.53 to 1.44 [31]. The mean LESS score for every condition (NF, IF, EF) was used as total LESS score. The total time for video analyzing was 30 min per patient (three series of three jumps).

The total LESS scores have good-to-excellent intrarater and interrater reliability based on ICC and standard error of the mean (SEM) values. For the intrarater reliability, the ICC and SEM range from 0.82 to 0.99 and from 0.19 to 0.52, respectively [31]. For the interrater reliability, the ICC and SEM range from 0.84 to 0.92 and 0.71, respectively [31]. Furthermore, the LESS has excellent expert versus novice interrater reliability and moderate-to-excellent validity for each item in assessing a jump-landing task [32]. The LESS scores from the first author (MB, Rater 1) were used for data analysis. Additionally, in this study, intrarater reliability was assessed by one researcher (MB, Rater 1) who scored all patients on two separate time points with at least 2 weeks in between the grading sessions. Interrater reliability was assessed by a second researcher (WW, Rater 2), who graded a randomly selected subgroup of patients that were scored by Rater 1 from the first grading session. Our own intrarater and interrater reliability study of the LESS is presented in the Supplementary material (Appendices II and III). It was demonstrated by the limits of agreement that only minor differences were seen between the raters, meaning that it is a reliable screening tool. This has also been demonstrated in other studies, and our findings are in line with previous results [27,32,33].

2.5. Statistical analysis

All data were normally distributed. Mean LESS scores for every condition of the patient (NF, IF, EF) were used for statistical analysis. To compare the mean differences between the groups when receiving different types of instruction, paired *t*-tests and two-sample *t*-tests were used. A visual inspection of the proportional distribution of IF and EF was compared to explore the differences between the conditions of the individual LESS items (Figure 4). No statistical hypothesis testing was performed. The data were analyzed using Stata version 16.0 (StataCorp, College Station, TX, USA). Statistical significance was set at $P \leq 0.05$.

A power analysis (G*Power for Mac, Version 3.1.9.6) was used to calculate the required sample size to test for relevant differences between the groups. Based on a similar study related to the effects of attentional focus during a jump-landing performance [15], a significance level of 0.05 and a power set of 0.80 resulted in a minimum of 27 patients for this study. To investigate whether a potential carryover effect had occurred, the testing sequence was examined by a visual inspection of the mean values. No statistical hypothesis testing was performed as the cohort only consisted of a small sample size.

3. Results

3.1. Descriptive data and LESS scores

Thirty patients (18 males, 12 females, mean age 23.26 ± 4.91 years) participated in the study. Descriptive data for the patients are presented in Table 1. The mean LESS scores of NF, IF, and EF were 6.71 ± 1.55, 7.06 ± 1.28, and 5.88 ± 1.34, respec-

Table 1
Patient characteristics.

Patients after anterior cruciate ligament reconstruction n = 30	
Gender (male/female)	18/12
Age (years)	23.26 ± 4.91
Time since surgery (weeks)	36.73 ± 8.54
Injured knee (right/left)	19/11
Type of graft (HT/BPTB)	16/14
Type of sport	Football: n = 22 Handball: n = 3 Basketball: n = 2 Hockey: n = 2 Korfball: n = 1

BPTB, bone–patellar-tendon graft; HT, hamstring tendon. Data are expressed as mean values ± standard deviation.

tively (Table 2), and there were no relevant carryover effects. There was a statistically significantly lower mean LESS score in EF compared with IF ($t(29) = 6.50$, $P < 0.001$) with a difference of 1.2 (95% confidence interval, 0.81–1.55) (see Table 3).

3.2. Individual LESS items

The proportional distribution of IF and EF were compared through visual inspection for the individual LESS items, and the most noteworthy items are mentioned. Patients instructed with IF appeared to have more trunk flexion at initial contact (item 7) and joint displacement (item 8) compared with EF. Patients instructed with EF appeared to have less knee valgus

Table 2
Landing Error Scoring System (LESS) score for different types of instructions in patients after anterior cruciate ligament reconstruction.

Type of instructions	Observations	Mean score	SD	Minimum	Maximum	Range
No focus of attention	30	6.71	1.55	3.67	10	6.33
Internal focus of attention	30	7.06	1.28	4.67	10	5.33
External focus of attention	30	5.88	1.34	3.33	8.33	5.00

SD, standard deviation.

Table 3
Two-sample *t*-tests between different types of instructions in patients after anterior cruciate ligament reconstruction.

Group	Variables	Observations	Mean score	SD	Mean difference (95% CI)	*t*-statistics	Degrees of freedom	*P*
Group A								
	Internal focus of attention	15	7.36	1.59				
	vs				1.51 (0.32–2.70)	2.61	28	0.015*
	external focus of attention	15	5.84	1.58				
Group B								
	External focus of attention	15	5.91	1.11				
	vs.				0.84 (0.11–1.57)	2.37	28	0.025*
	internal focus of attention	15	6.76	1.49				

CI, confidence interval; SD, standard deviation.
* Statistical significance.

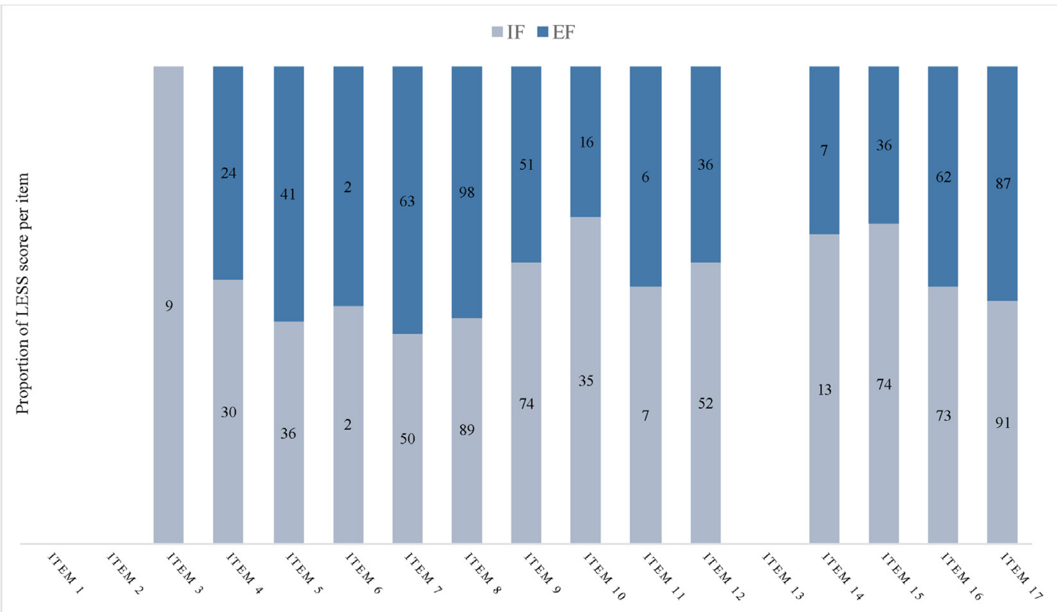

Figure 4. Stacked bar graph showing the proportional distribution of the individual Landing Error Scoring System (LESS) (number of observations) items between internal focus of attention (IF) and external focus of attention using a target (EF) in patients after anterior cruciate ligament reconstruction.

(item 9) and valgus displacement (item 16), lateral trunk flexion at initial contact (item 10), narrow stance width (item 12), and more symmetrical initial foot contact (item 15) compared with IF. Items 1, 2, 6, 11, and 13 showed minor or no differences between IF and EF. An overview of the scores of the individual LESS items between IF and EF can be found in Figure 4.

4. Discussion

The main finding of this study was that EF results in a significantly better mean LESS score compared with IF in patients after ACLR. This means that a better jump-landing was achieved with the use of EF. Moreover, the individual LESS items showed that EF appears to result in less knee valgus and displacement, narrow stance width, lateral trunk flexion, and more symmetrical landing at initial contact compared with IF. These findings confirm the initial hypothesis and emphasize the potential of using a target as EF to improve the jump-landing technique in patients after ACLR.

A possible reason for the findings in this study might be explained by the effects seen with the use of focus of attention. Wulf et al. proposed a "constrained action hypothesis," which states that when individuals consciously focus on the movements of motor performance, it disrupts the automatic motor control processes that regulate coordinated movement [34]. When patients during a practice session are told to focus and consciously control their movements, the automatic motor control processes are interrupted instead of allowing a non-conscious motor behavior that controls movements more efficiently [34]. Conversely, directing attention externally allows the motor control system to naturally regulate and organize the motor performance, allowing movements to be fast and reflexive [35]. This hypothesis possibly explains why patients in this study had a better jump-landing technique when receiving EF. Moreover, previous studies have also shown that EF promotes better motor performance and skills and gives a more prolonged learning effect [17,34]. There might also be other possible alternatives that explain the findings, such as underlying neural mechanisms [36–38]. However, this is beyond the scope of this study.

Other studies have also shown the beneficial effects of using EF compared with IF [11,12,14,16,29,39,40]. However, these studies used only verbal instructions without using a target as EF, and previous research has mainly been performed on healthy subjects. This indicates that limited research has been carried out on the possible beneficial effects of using a target as EF in patients after ACLR. In a study by Gokeler et al., it was shown that EF had beneficial effects in both jumping distance and knee flexion angles in a single leg hop compared with the use of IF in patients after ACLR [15]. Patients who received IF ("Jump as far as you can. While you are jumping, I want you to think about extending your knees as rapidly as possible") showed a decreased knee flexion angle compared with EF ("Jump as far as you can. While you are jumping, I want you to think about pushing yourself off as hard as possible from the floor"), resulting in a stiffer knee landing, potentially increasing the load on the knee and thereby increasing the risk of a second ACL injury [15,41]. These findings are in line with the results of the current study showing that receiving EF results in a better jump-landing technique in patients after ACLR.

Besides verbal instructions, there are other ways to create an EF. A systematic review by Benjaminse et al. suggested that an EF can be created using analogy techniques and auditory cues [13]. In addition to the findings of this review, studies have shown that visual feedback is an efficient tool for improving knee kinetics and kinematics [42–44]. However, these studies were only performed on healthy subjects. Therefore, more research is needed to investigate the effects of using verbal EF instructions, analogy techniques, auditory cues, and visual feedback in movement techniques in patients after ACLR.

Furthermore, patients instructed with EF appeared to have less knee valgus at initial contact and valgus displacement. In several studies, the position of dynamic knee valgus alignment of the lower extremity is described as the position in which the knee joint collapses medially, representing a coupled motion due to the combination of hip adduction, hip internal rotation, knee flexion, knee abduction, and tibial rotation [45,46]. This position has been shown to increase strain on the ACL and might have a relation with the prediction of a second ACL injury [47]. Training with EF might be beneficial to reduce knee valgus and displacement during jump-landings. Similarly, in the current study, EF appeared to have less lateral trunk flexion at initial contact. This is in line with the study of Hewett et al., which showed that lateral trunk position and knee abduction angle are biomechanically linked [48]. If the trunk moves laterally, the ground reaction force follows, which results in a greater lever arm relative to the knee joint centre [49]. This indicates that lateral trunk flexion increases the knee abduction angle, loading of the knee and its ligament during a dynamic task. To counteract the lateral trunk flexion and increased load of the knee, it is essential to activate the hip adductor torque to maintain an upright stance and dissipate the forces of the lower extremity [48]. Deficits in the neuromuscular control of the trunk during landing and cutting activities might lead to uncontrolled lateral trunk flexion, thereby increasing the knee abduction angle. Thus, insufficient neuromuscular control of the trunk may increase the load of the ACL and the risk of an injury [48]. The knee abduction angle appears to be directly influenced by trunk positioning during dynamic tasks [50–52]. Another aspect that might influence this angle is the stance width due to the influence of the body's center of mass relative to the knee joint. An increased stance width during jump-landing tasks has been shown to cause greater moments in the knee joint, causing potentially high-risk movement patterns that could result in a non-contact injury [53]. Another important aspect of a better jump-landing technique is a symmetrical initial landing, which was more achievable with EF. Research has shown that neuromuscular deficits such as muscle weakness and neuromuscular control often persist for months or even years after surgery [3,6,45,54–56]. As a result of neuromuscular deficits, asymmetrical landing and loading might occur, where a serious short-term consequence appears to be an increased risk of a second ACL injury in the ipsilateral knee or even contralateral knee [57].

Research has suggested that the contralateral knee represents some form of protection for the reconstructed knee [58]. Thus, altered contralateral loading patterns and compensatory movement patterns after ACLR are not unusual and might explain the increased load on the contralateral knee during dynamic movement tasks [59,60].

Study limitations

The study cohort was relatively small and homogenous in terms of age, activity, and sports, meaning that it may not represent a more varied and larger target population. Another limitation is that the study was made as a within-subject design. However, as there was no carryover effect, it is unlikely to have affected the overall results, where EF is superior to IF in jump-landing technique.

The LESS is a clinical assessment of movement patterns. However, we did not measure three-dimensional lower extremity kinematics and kinetics during this study, making it possible to measure and compare other specific movement quantities during movement analysis under different conditions. Another limitation of the LESS is that it cannot be assessed in real-time, as it requires the use of video cameras. Furthermore, time and expertise are needed to analyze videos subsequently.

Clinical implications

The findings of this study showed that most patients had a better jump-landing technique by having a lower mean LESS score when using a target as EF compared with IF. However, there were large inter-individual differences between the patients, meaning that some experienced a better jump-landing technique with EF compared with IF, whereas others only showed minor differences between the two types of instructions. This indicates that training programs are not 'one-size fits all' and should be specifically adjusted for those susceptible to EF. To find out whether a patient is benefitting from either IF or EF, it is suggested that the earlier stage of rehabilitation contains exercises where both types of instructions and targets are applied to observe how the movement quality of the patient is affected.

It is assumed that most instructions given within the ACLR rehabilitation are IF, however, based on the results from this study, it could indicate that increased use of EF might be applied to improve the jump-landing technique. Nevertheless, IF might be more suitable in the early stage of rehabilitation due to increased bodily awareness. However, along with the progression in the rehabilitation phases, movements are expected to become more automatized. Therefore, EF might be more appropriate to redirect attention to relevant environmental cues by facilitating a more sport-specific rehabilitation. Other types of EF (e.g., visual and auditory feedback) might also be important to consider in the rehabilitation of patients after ACLR.

Future research should focus on whether training with EF results in retention after several training sessions. Moreover, testing the individual LESS items on a larger cohort would also provide a better understanding of a jump-landing technique in patients after ACLR.

5. Conclusions

This study showed that using a target as EF resulted in a significantly better jump-landing technique than IF in patients after ACLR. Therefore, the use of EF during ACLR rehabilitation allows patients to redirect attention to environmental cues and might potentially decrease the risk of a second ACL injury compared with IF, which is predominantly used in the current practice. This indicates that increased use of EF could or might result in a better treatment outcome during ACLR rehabilitation.

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Ethical Approval

Ethical approval was obtained from the institutional review board of the University of Groningen.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.knee.2023.04.016.

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