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Is there a Difference between Knee Valgus Angles on Landing during Different Hop Tasks?

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Abstract

Objective: A brief review of the literature to provide an overview of knee valgus angles during different hop tasks.

Methods: A literature search was conducted; electronic databases used included PubMed, and SCOPUS. The inclusion criteria were English language, and publication between January 2010 and May 2015, which assessed the knee valgus angles during hop landings. The studies were evaluated by the researcher through their titles, abstract, as well as how the investigation functioned according to the inclusion/exclusion criteria of the present study.

Results: A total of 2 papers were included with full-text, as various studies incorporated designs for knee valgus testing which resulted in alternate findings that could not be analysed or evaluated.

Conclusion: No extensive research has been carried out over the past 5 years to evaluate knee valgus angles during hop tests. However, the current study found that the majority of the published studies during 2010 – May 2015 focused on evaluating the performance of landing tasks among participants in different sports (basketball, volleyball). Moreover, it can be concluded from the present review that there still exists failings in the evaluative results from past studies regarding the definitive comparisons between knee valgus angles upon landing, which occur through the measurement of important variables in the utilisation of 2D video analysis (i.e. when using crossover hop tests to measure knee valgus angles).

Keywords: Functional performance and hop tests; Knee valgus on landing; Knee valgus during hop

Introduction

Many injuries of the knee including the anterior cruciate ligament (ACL) have been shown to be the result of a relationship between either the degree of knee valgus or how the knee is positioned during functional tasks [1,2]. This is also associated with injury to the patellofemoral joint [3]. Therefore, a test can prove indicative for the identification of those people who may be susceptible to injury through the process of evaluating the angles of the knee valgus, which can be completed through a certain tasks. For instance, these tasks can include: the drop jump (DJ) drop landing, the single-leg landing (SLL), and the single-leg squat (SLS) [2-8].

The majority of investigations have utilized a 3-dimensional (3D) motion capture for analysis, which provides a measurement of the biomechanics within the lower extremities, as this is commonly perceived as the gold standard evaluative form of assessment in this manner of research. Conversely, analysis through 2-dimensional (2D) video, which has already been used during SLL, SLS, the drop vertical jump, and step landing, measures both the knee valgus angles of the population as a whole (both injured and uninjured), as well as for just athletes [3,5,9,10]. Similarly, a reduced amount of frontal-plane dynamic knee valgus through athletics' training evaluation and active programs of intervention may be feasible through the analysis of a 2D video, as this form can prove cheaper, easier to use, and quicker, than an analysis through 3D motion [10].

A crossover hop test, and single leg hop test have both been utilised as specific forms of the Functional Performance Test (FPT), as ways to document an athlete's progress through forms of training, as well as through the measure of levels of recovery of lower extremities following injury or surgery, which are frequently used in both clinical and field settings [11]. The findings of a hop test have the potential to show differences between injuries [12-15]. Thus, a hop test has developed into the most commonly used FPT, as a way to describe an injured patient's function, although those without injury may also have their legs analyzed in order to assist in highlighting the potential power and strength evaluation [16].

In addition, some previous studies investigated the connection between ACL injuries and landing methods. Zahradnik et al. determined the relation between ACL injuries and various landing techniques are used by volleyball players [17]. Moreover, some studies extended on the FPT evaluation by focusing on distance evaluation and improvement. The study by Herrington [18], which was carried out by female basketball players, measured the effects of jump training on knee valgus angles through a 4-week period on a landing knee valgus and hop distances through a crossover hop test, even though they were separately documented. However, by the possibility of detecting the differences of knee valgus angles (frontal plane projection angle; FPPA) when a single leg hop test and crossover hop test are

undertaken through the use of a 2D video analysis, clinicians and researchers will gain more confidence in administering, which will also create a reduction in fatigue that is caused by over-testing. It will then be possible to assess the development of injured limbs by comparing their performance beside knee valgus angles to uninjured limbs during one hop test, together with measuring the muscular strength with knee valgus angles in a healthy population.

Therefore, the current review's principle objective has been to provide an overview of the knee valgus during different hop tasks by investigating the ability of hop tests to evaluate knee valgus symmetry using a 3D motion or 2D video analysis. Nevertheless, the majority of the published studies during 2010 – May 2015 focused on evaluating the performance of landing tasks among participants in different sports (basketball, volleyball). Therefore, the current review will investigate these studies, which focus on basketball and volleyball, to discern the studies' approaches over the last 5 years. The initial keyword search is functional performance and hop tests, knee valgus on landing, and knee valgus during hop, and the researcher performed the study-selection process and the literature search individually. During the last 2 weeks of May 2015 a computer-based online literature search was performed using PubMed and SCOPUS (2010 to May 2015).

Method

Literature sources and study selection

The researcher performed the computer-based online literature search using PubMed and SCOPUS (2010 to May 2015), during the final 2 weeks of May 2015. Advanced searches used the keywords: functional performance and hop tests, knee valgus on landing, and knee valgus during hop. Searches were limited to articles in English and human subjects. Google Scholar was also searched using the same keywords, and searches were limited to the first 10 pages of results. A summary of the search strategy is provided in Table 1.

Database	Search terms	Results	Qualified	Obtained
PubMed	Knee valgus on landing	103	1	1
	Knee valgus during hop	7	2	1 (1 repeat)
	Functional performance and hop tests	44	1	0 (1 repeat)
SCOPUS	Knee valgus on landing	126	1	0 (1 repeat)
	Knee valgus during hop	12	2	0 (2 repeat)
	Functional performance and hop tests	68	1	0 (1 repeat)
Google Scholar	Same key words as above			0 (2 repeat)
Hand search				0
Total				2

Table 1: Search summary

Determining inclusion and exclusion

There were no restrictions on the study design, as articles whose titles and abstracts suggested possible inclusion were obtained in full text for more detailed assessment of eligibility. These forms of literature selected were evaluated when they showed knee valgus angle assessment during hops, if a full-text article was available, and when the investigation had been approved by a review board of ethics. All forms of animal or cadaveric investigations were excluded from the criteria. Subsequently, following the studies that were perceived to meet the selection criteria, a more specific hand search was conducted for any relevant articles that had previously been missed.

Discussion

It has been documented that various knee injuries are a result of the knee valgus position during functional tasks, including anterior cruciate ligament (ACL) injuries [1,2]. In fact, when the knee abduction position starts to increase, there becomes a significant injury risk in relation to the patellofemoral joint [3]. A screening test for the evaluation of knee valgus' angles may prove necessary to identify individuals who become prone to injury.

Both a crossover hop test and single leg hop test have previously been used as a Functional Performance Test (FPT), these are commonly utilised in both clinical and field settings [11]. The majority of studies, which relate to FPT and knee angle measurements, include several forms of testing. Barendrecht et al.'s study incorporated a drop jump, together with a single leg hop for distance to assess both knee kinematics and stability [19]. This example presents how hop tests are considered as a significant test. Therefore, over-testing and time consumed will be controlled if the hop test is used as a knee kinematic measurement as well.

The current review's principle objective has been to provide an overview of knee valgus during different hop tasks. The initial keyword search and identified articles are provided in Table 1 above. Following a first selection of careful screening based on full text articles, as well as titles and abstract, two articles met all inclusion criteria, as limited research has been observed on measuring knee valgus angles during different hop tasks. Those articles were published in 2014 and 2011. Moreover, this review will investigate the studies, which have focused on evaluating the performance of landing tasks among participants in different sports (basketball, volleyball) to find out the study approach in the last 5 years.

Knee valgus during hop tests

The present investigation has found that only two studies evaluated knee valgus angle during hop tests. One study evaluated how both internal and external factors were affected during a single leg hop for distance, which helped define the base effect of patients' knee joint kinematics following ACL reconstruction (ACLR) [20]. That specific study was structured through seven female patients and nine males, who played a variety of sports: 9 for football, 5 played handball, 1 participated in basketball, and volleyball comprised 1 patient. Thus, it can be concluded that the variation in sports may affect landing performance results. Munro et al. found that basketball players had greater frontal plane projection angle values than football players during SLL [21]. Therefore, there must be a focus on the detection of the knee valgus angle differences between two groups in a specific population in order to decrease the effect on landing performance results. Likewise, the current investigation has found that all studies of prevention training programs focused on a specific population to evaluate the effects of prevention training programs on knee valgus [18,22-24].

One of the Inclusion criteria for the patients in Gokeler et al. study was that the patient exceeded more than four months after ACLR [20]. A between group experimental design was implemented by Gokeler in order to analyse the effect of 2 verbal instructions, which could promote either an internal or external detail of performance from a single leg hop test for measuring distance. Firstly, instructions such as, "Jump as far as possible, and extend your knees as quickly as you can during the jump", were said to the internal focus group. While, the groups of external focus received instructions such as, "I need you to push off as hard as you can in order to jump as far as possible". However, the knee valgus angle at the initial point of contact and peak knee valgus angles showed no significant differences between the internal focus and external focus group.

The study by Ortiz et al. attempted a comparison that used uninjured women and women with ACLR to show the mechanics of landing and the muscle activity through EMG for legs during maneuvers of both side hopping and crossover hopping [25]. Twenty-eight physically active young women (13 with ACLR and 15 healthy) participated in the study, and the average recovery period for women following ACL reconstructive surgery was 7.2 ± 4.2 years (range, 1–16 years after reconstruction). In contrast to Gokeler's study, Ortiz's investigation did not use a variation in sports, as all the participants were recreational athletes, where the side-to-side task was subdivided into side and crossover hopping components. A side-hopping maneuver was defined as the direction of movement to the opposite side of the weight-bearing leg. A crossover hop was defined as the direction of movement toward the same side of the weight-bearing leg. For example, if the participant jumped with her right leg toward her left leg, the maneuver was considered to be a side hop. If the subject jumped toward her right side, the maneuver was considered to be a crossover hop.

Ortiz found unexpected results, as knee valgus moments during the side hop (crossover maneuver) were greater in the control group than in the women with ACLR. In addition, the ACLR group exhibited greater knee abduction moments during the side-hop maneuver. Nevertheless, both of Gokeler's and Ortiz's studies could not determine specific period after ACLR, and they did not consider the surgery type of ACLR (Patellar tendon graft, Achilles tendon allograft, Gracilis-semitendinosus graft). Alterations in muscular performance and level of physical activity change, according to time of injury, might have an effect on functional parameters and performance of various tasks [26,27]. Therefore, future studies should limit the range of time after surgery to control for this potential bias [28]. Furthermore, definitive contrasts were shown by the knee movement assessment between patients with ACL, who had received the reconstruction of hamstring tendons compared, and patients where the patellar tendon was reconstructed [29]. Consequently, future studies should be considered in relation to the surgical approaches of ACLR to minimize differences potential.

Knee valgus and volleyball

Through the sudden changes in direction or speed during physical activities, non-contact ACL injuries are common in younger individuals with higher levels of health [30]. Indeed, volleyball is the sport where ACL and medical intervention are most common, and the greater percentage of injuries occur within women that play volleyball, although more ACL injuries happen during the ages of 11-19 [6,31,32]. Overall, the present investigation has concluded that four studies evaluate knee valgus during landing after a volleyball block. Therefore, the present review will discuss these studies to find out their approach.

One specific study by Zahradnik et al. who used a sample of fourteen professional volleyball women, determined the connection between the landings of step-back, stick (does not incorporate a subsequent move) and run-back after a block, as well as selecting the risk factors of ACL injuries, as various landing techniques are used by volleyball players through both successful and unsuccessful blocks [17]. The most common form is for players to use either a stick landing or a step-back when using a successful block, but a run-back landing with an unsuccessful block. When a stick landing is performed, both feet are positioned in parallel when ground contact is made, with the possibility to stand up-right without over-balancing. The step-back landing is a slight modification, as the player need to use the right foot to step back from the net immediately upon landing. Contrastingly, the run-back landing is common within the movement of the game where feet are basically positioned parallel at the moment of ground contact before the player is required to move away from the net to a distance of about 3 metres immediately upon landing as quickly as possible. All together and individually, the conglomeration of these movements impact heavily upon the biomechanical factors that increase the risk of ACL injuries. Furthermore, Zahradnik's study has demonstrated that the peak moment for valgus to be a risk factor for ACL injuries happens when the run-back landing occurs of landing, as this exerts the highest vertical reaction forces.

The second study by Zahradnik et al. compared lower extremity mechanics and energy absorption during two types of landing after a successful or unsuccessful block in volleyball, and assessed the risks of injury to the anterior cruciate ligament [33]. In total fourteen elite male volleyball players were involved in this study, who were evaluated during stick landing or step-back landing techniques (with the right lower extremity stepping back away from the net) after performing a standing block jump movement. It was discovered that the maximum knee valgus moment was significantly greater (by 52% for the right lower extremity and by 12% for the left lower extremity) during the step-back landing. Nevertheless, the methods used in both Zahradnik's studies were similar, and by looking at Table 2 we will find that the knee valgus moment was greater in male players [17,33].

	Valgus moment of	Stick landing	Step-back landing
Zahradnik	Female	0.014	0.015
Zahradnik	Male	0.25	0.38

Table 2: Knee valgus moment (Zahradnik's studies)

In contrast, Hughes et al. [34] study evaluated how knee kinetics in university volleyball players of both genders was affected during block jump landings, which demonstrated that a maximized knee valgus moment was significantly lower in males those in females. Males generally contacted the ground in a valgus position which was maintained throughout the landing phase. Conversely, the female players normally made contact with the ground with the knee angle in a valgus position in the frontal plane, which started to develop continuously from the initial contact on the ground to the maximum moment.

Finally, Hughes et al. study focused on the how the opposition on knee kinematics and the force of ground reaction, as well as gender, became affected through the landing process of a block jump with both

gender university volleyball players [35]. That specific study was structured with 6 female and 6 male participants, and the findings indicate that definitive contrasts exist between genders in the frontal plane kinematics. However, no significant effect was shown to be present between genders for knee valgus at the point of initial contact, which similar studies have documented [36]. Nevertheless, both ROM of knee valgus and maximum knee valgus highlighted a significant effect between genders, as men presented a lower knee valgus angle than females during the landing process. Overall, though, the previously documented studies did not consider the hop performance test, and focused purely on the landing after a volleyball block in their investigations.

Knee valgus and basketball

The prevention of ACL injuries has developed into key component of sport within the modern era. The majority of training programs that help prevent ACL injuries are comprised of agility training, balance training, plyometrics, as well as the formulation of instructions to help avoid the stance that is characteristic with ACL injuries: the slight knee flexion and forceful valgus rotation [1,37]. Nonetheless, training programs can be designed differently, and the findings that are shown present a decrease in the incidence of ACL injury [1,38]. Furthermore, certain studies have looked into how training programs affect knee kinematics during the workings of landing tasks, although findings have not always been symmetrical [5,10,14,15,21,23-25,28,29,37-44]. Indeed, knee flexion has been shown to rise due to conducting plyometric or balance training [41], plyometric training [39], and feedback from videotapes [43]. Similarly, the knee abduction angle during a medial drop landing was changed through the kinematics of the knee in the frontal plane, as there was a decrease in both plyometric and balance training [41]. Likewise, different investigations presented no knee valgus differentials following either agility training or plyometric [39,44]. Generally, the present review has concluded that four studies evaluated the effects of prevention training programs on knee valgus during landing of basketball, which showed differences in the duration and types of prevention training programs. Therefore, the present review will discuss these studies to find out their approaches.

The period of prevention program of the first study by Otsuki et al. lasted 6 months, in which sixty female junior high school basketball players were subsequently divided into two groups: a control group of 28 participants, and a training group consisting of 32 [24]. The control group persisted with a routine of regular exercise, whereas the training group undertook a 6 months program of injury prevention program. Within this program of training, there was a measurement of both the knee flexion range of motion and knee valgus motion that occurred in a drop vertical jump, which was measured pre- and post-training. The study also evaluated the possibility of a high knee abduction moment (pKAM) through the use of an ACL injury prediction algorithm, which lasted 20 minutes and was set-up as a practice session. Overall, this was performed 3 times per week by the training group, although the research discovered that it was within the control group that the knee valgus motion significantly increased, as well as the pKAM. In fact, it was also within the control group that the knee flexion range of motion significantly decreased. In addition, no significant development was observed, although injury prevention training was capable of limiting the alterations in knee mechanics, as prior investigations developed the concept that female athletes within high schools improved knee mechanics in both the frontal and sagittal planes through injury prevention [5,14,15,23-25,28,29,37,38,41-44]. Nevertheless, a starting point to prevent ACL injury can be seen through the limitation of changes in knee mechanics during this period might be, as with certain athletes it could be possible to reduce the risk of ACL injury, while further training would be required for those who are at greater risk. What is more, it was observed through the subjects in Otsuki's study that students between 12-14 years old may not present a representative cross-section of children of that early pubescent stage, as certain subjects were stipulated as being in either the middle or late pubertal stages.

A different study presented the effects of a 3 months prevention program on the jump landing technique in basketball with a sample size split between 53 athletes in the intervention group 63 athletes in the control group, where both groups received instructions to refrain from altering their amount of general training strategy [22]. Originally, the intervention group received a program of prevention that was required to be undertaken in addition to the normal routine training, with a warm-up practice twice per week that lasted 5 - 10 minutes each time. It was found by Aerts et al. that knee valgus during landing diminished significantly in the female intervention group in comparison to their control group following the completion of the jump-landing prevention program [22]. In contrast to Otsuki prevention program, Aerts program was shorter and diminished female knee valgus. However, the average age of Aerts study was 15-41 years of age. Additionally, comparatively to Otsuki's and Aerts's investigations, other research studies investigated the effects of prevention training programs during weeks [18,23].

The length of a training program of prevention through Nagano et al. study for female basketball players was five weeks, with the aim to distinguish how balance from jumping training programs on knee kinematics was affected, which included rotation of the tibia, together with electromyography of the quadriceps and hamstrings [23]. The program consisted of duration of practically 20 minutes each day, three times per week, where the subjected performed jump and balance training to increase their landing skills, while practicing their fundamental basketball skills. For the initial three weeks of the program was described as the technical phase (Phase 1) that attempted to develop landing techniques through three foundation techniques. Firstly, the subject was instructed to perform a soft landing with a great bend to the ankle, hip and knee joints; secondly, each participant had to land on the ball of their foot while maintaining the trunk leaning forward; thirdly, the subject was informed to maintain the subject's knee neutral without medial motion. Subsequently, the second phase, which was based around performance was brought into last two weeks, and focused upon increasing the training intensity, alongside how to use proper techniques throughout several movements. Moreover, through both pre- and post-prevention programs, both knee kinematics and tibial rotation were evaluated as the individual subjects performed a single limb drop landing from a height of 30 cm, although overall the training program di not present an effectual change to the tibial rotation and knee varus/valgus. Conversely, the findings in relation to the angle of knee flexion in post-training were significantly larger than that for the Pre-training, although the statistical power for the valgus was low. The amount of participants in this study was low with only 8 female athletes, thus it would be difficult to highlight the miniscule alterations in knee valgus. Similarly, previous studies have reported no marked differences for frontal plane knee motion in knee valgus during the landing of a single limb landing following agility or plyometric or training programs, which demonstrated that it may not be possible to detect the change in frontal plane knee motion when there is a possibility of a single limb drop landing [39,44]. While a separate report has shown that the knee abduction angle is decreased

during a medial drop landing within both balance and plyometric training [41].

Jump-training programs have demonstrated improvements for both functional performance and landing knee valgus [1,5]. Moreover, these training programs can also reduce ACL injury rates for female athletes and most of them last for between 6 and 8 weeks, with 20 minutes to 1 hour sessions over the period of 3 days per week [1,40,42]. In contrast, the duration of jump-training program in Herrington's study was 4 weeks, as that study was designed for an assessment of a program of jump-training that could create similar effects to those previously reported [18]. During Herrington's study, an assessment took place of the knee valgus angles during 2 landing tasks, a drop jump landing, together with a jump shot landing, as well as a crossover hop distance both pre- and post-progressive programs of jump training for 15 female basketball players. Altogether, the program constituted of 15 minute sessions 3 times every week, for a complete duration of 4 weeks, which highlighted that significant developments in crossover hop distance and knee valgus angles on drop-jump landing could be decreased, as well as a functional jump-shot test. Nonetheless, prevention training programs are not always sufficient to minimize ACL injury risk, as it may also be affected by participants' age, program duration and evaluation tasks. Therefore, reevaluating these programs is recommended when regarding a target population

Conclusion

The present investigation has found that only two studies evaluated knee valgus angle during hop tests [20,25]. Nonetheless, the majority of the published studies between 2010 and May 2015 focused on evaluating the performance of landing tasks among participants in different sports (basketball, volleyball). These generally were vertical landings off a box, this review shows the need for further research looking at horizontal landing from tasks such as hop. Four studies evaluated knee valgus during landing after a volleyball block as a specific task for volleyball players, in order to determine which task may cause a high risk to knee kinematics. Likewise, four studies evaluated the effects of prevention training programs on knee valgus during landing of basketball. However, it has been concluded through the present review that gaps still persist in the findings from past studies in regards to the difference between knee valgus angles on landing through the measurements of distinct variables in the analysis of 2D video utilization, such as the difference between knee valgus angles on landing during different hop tasks (crossover, triple hop, 6-m hop). These hop tests are among the principle FPTs [12,23,45-48]. Indeed, the hop test is perceived to strongly indicate the foundation for measuring the cross-reference of uninjured athletes' lower extremities against individual athletes who had received rehabilitation post-injury, as this can assist in determining the predictability of return to sport [12,14,46,49,50]. Likewise, this practice was generally formulated in either clinical or field environments, so that the development through the program of training could be assessed, as well as an evaluation of kinesthesia, power and strength [8,51,52]. It has been demonstrated through many studies of injured athletes that hop tests are capable of signifying lower-limb symmetry, and as a consequence these can be implement to comprehend the dynamics of a patient [11-13].

In addition, hop tests are generally proven to be reliable, and are believed to function in the assessment of limb symmetry, together with the documentation muscular strength and power in both injured athletes and individuals who are healthy [9,16,53-57]. Certain studies of the past have expanded on the evaluation of FPT through the distinction on how to improve and evaluate distance. For instance, the effects of jump training on knee valgus angles in female basketball players, through a 4-week period on a landing knee valgus and hop distances through a crossover hop test, was measured and documented by Herrington [18]. However, the present investigation was structured around how relevant the crossover hop tests in the progress of FPT, as the function of knee valgus angle measurements through the analysis of 2D videos was carried out, together with an improvement on the limited research of the past that combined the two elements.

Practical application

The majority of research, in relation to FPT and knee valgus measurement, contains various forms of testing that has the objective of achieving certain aims [18,19,29]. For example, one investigation assessed both knee kinematics within a drop jump, together with the stability with a single leg hop for distance [19]. Similarly, a different study incorporated 2 different landing tasks that brought together drop jump landings from a jump shot in order to analyse how the knee valgus angle changed within this process, which also functioned together with a crossover hop test for distance that measured distance progress [18]. Nevertheless, no evidence has been found from prior investigations that demonstrate the difference between knee valgus angles on landing when measuring significant variables using 2D video analysis focused on the recreational athletes, such as knee valgus angles during single leg hop test and crossover hop test. Therefore, Prove hop tests ability to assess the difference between knee valgus angles will makes investigators capable of implementing one definitive task to their research. Indeed, it is feasible to save the time of both athletes and researcher's through the simultaneous assessment of knee valgus angles and functional performance by the implementation of one hop test, which will also help lower fatigue that results from extensive testing.

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