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Comparison of knee injury of basketball players with different pro—hop modes in kinematic perspective: time period, factor and intervention

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Abstract: *Rapid movement techniques in basketball are prone to acute and chronic injuries to the cruciate ligament and internal knee joint movements. This study analyses the biomechanical changes of the non-axial foot after different pro-hop braking from kinematic and kinetic perspectives, in order to provide input to the teaching, intervention and competitive training of basketball pro-hop in basketball. Kistler force measurement, Vicon Motion 3D motion capture and Biovision EMG were used to describe the kinematic and kinetic parameters such as the angle of the knee joint, joint moment, angle at maximum moment and the co-contraction ratio of the rectus femoris and biceps femoris muscles during the landing phase of the non-axial foot after pro-hop and braking in three different pro-hop patterns of female basketball players. The study found that,(1) The pro-hop followed by the non-axial foot initiation technique in basketball movement is prone to knee cruciate ligament injuries, mostly occurring in the first 20% of the landing phase. (2) The angle of the knee joint during the non-axial foot landing phase, the joint moment, the angle at maximum moment, and the co-contraction ratio of the rectus femoris to the biceps femoris muscle govern the risk of non-axial foot initiation injury at the end of the pro-hop. (3) The mechanical load on the knee joint during the non-axial foot landing phase of the one foot pro-hop. (4) The co-contraction ratios of the rectus femoris and biceps femoris were significantly different between the in situ, one foot and double-leg pro-hop. Conclusions, (1) The first 20% of the non-axial foot activation phase after one foot pro-hop is more likely to lead to cruciate ligament and other knee injuries, significantly different from the in-situ and double-leg pro-hop patterns. (2) The lower co-contraction ratio of the rectus femoris and biceps femoris provides protection, support and activation of many peripheral knee muscle groups, partially reducing energy expenditure and improving the quality of movement completion. (3) The training load, injury severity, and The weight and angle of the non-axial foot in different modes of pro-hop and braking can be adjusted to allow for active rest and dynamic compensation of the knee joint under load and movement.*

Keywords: *basketball, knee, pro-hop, anterior cruciate ligament, landing*

1. Introduction

Basketball is a competitive sport that is played on the same court, in a set space, with limited time and regulations, and where the rules of winning are based on the transformation of the team's attack and defence and the number of points scored. The standardised and scientific use of mobile movements is often overlooked and abandoned by young people, resulting in various degrees of injury due to the use of mobile steps characterised by pro-hop without the ball or after receiving the ball, followed by step and crossover breaks. The rigidity of previous studies from a sports biomechanics perspective [1] , statistical comparison of sports injury sites and populations [2] , and the niche nature of the sport and the small number of groups involved [3] have limited the comprehensive analysis of human kinematics of the knee joint in movement-based, multi-frequency, ultra-vigorous, and strong confrontation scenarios, and accordingly lacked recommendations and implementation for assessment, prevention, and intervention. and implementation of recommendations within the scope of intervention. The study takes as an entry point the practical problem of sports injuries caused by the force of the landing foot pro-hop in the basketball sport, and empirically demonstrates the kinematic, kinetic and training-specific statistical descriptions and multivariate speculations of the technical movements, identifying the human movement characteristics and injury risk mechanisms in the situations of acceleration, deceleration, cushioning and braking. The aim is to provide a theoretical reference for the improvement of movement quality and the evaluation and prevention of sports injuries in basketball.

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2. Review of the literature

Basketball is an intense, physical sport with a low centre of gravity, alternating between acceleration and deceleration, and braking and starting, where the knee joint is used very frequently. A survey of sports injuries among university students in China found that the knee injury rate was 27.1%, and even higher among basketball fans. Acute osteoarthritis and chronic osteoarthritis complications in the short and medium term, which occur in youth, women and physical activity, are attracting more and more attention and input from experts in sports medicine, rehabilitation and sports training, and have led to a number of research findings and empirical evidence. For example, jumping catches (landing on two feet after catching the ball) are often used to get rid of defenders for effective scoring space, stride catches (landing on one foot after catching the ball) are often used in passing and cutting play combinations to break through with the ball, etc. All of these are caused by more weight bearing on the lower limb joint forces when getting rid of defenders and seeking cutting action, and large knee valgus angles, resulting in ACL tears or ruptures in the knee joint. X.Shi [4] Research suggests that ACL injuries have roughly a 70% probability of occurring during non-contact sports with sudden decrements or changes in direction (lateral strides or steering cuts). The study by Q.Chen [5] also supports the conclusion that ACL injuries are more common during directional changes, sudden stops, steering accelerations, rotations and landings after jumps, and are much more likely to occur during movements such as lateral strides, sudden stops and cross strides, where the combination of different force directions such as flexion-extension, inversion-external and internal-external rotation interacts with each other, than in straight movements. To address the symptoms and causes of these sports injuries, scholars have attempted to investigate the kinematics, dynamics and muscle co-contraction of the non-axial foot knee through the use of kinematic techniques based on quantitative assessment and interventions of different landing patterns (landing in place without acceleration, landing on one foot with acceleration and landing on two feet), knee flexion angle, fetching intermuscular activation ratio and knee and femoral muscle group strength. The study was conducted to investigate the constraints of knee injury reduction. The study follows previous research ideas and methodologies, such as strengthening the anterior and posterior quadriceps and posterior leg muscles to protect knee stability, and relieving excessive ACL forces and loading. Through the empirical analysis of the knee joint in different modes of landing and pro-hop movement of college women basketball players, the study aims to prevent and diagnose the practical problems of sports injury prevention and control in the basketball sport characterised by movement techniques and common sports injuries in youth groups.

3. Study population and sample

The population of this study was non-professional and general A-team women's basketball players from domestic higher education institutions. Twenty-five basketball players from Zhejiang Yuexiu university and Shaoxing University Yuanpei College participating in the Zhejiang University Basketball Association (ZUBA) and Women's Division A in 2021 were used as the study sample. Their mean height was 167.7±5.0 cm, mean weight was 60.4±5.6 kg and their training years were roughly 7.1±1.2 years. The sample subjects were free of ACL injuries and informed of the purpose and procedures of the experiment and signed an informed consent form before the experiment.

4. Research methodology

4.1 Literature method

Using the academic digital platforms such as China Knowledge Network and the National Database of Academic Journals of Philosophy and Social Sciences, the research was searched with the themes of "basketball", "knee joint", "cruciate ligament" and The study is based on the themes and keywords of "basketball", "knee joint", "cruciate ligament" and "pro-hop", which provide the justification for the selection of the topic, ideas and methods, making the study novel, theoretical and feasible.

4.2 Experimental test method

4.2.1 Experimental design

The three types of pro-hop are, (1) One-footed pro-hop, Accelerate from the ready position towards the board, land with the right foot on the board and then quickly leave the ground and dribble to the left.

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(2) Two-footed pro-hop, Accelerate from the ready position and catch the ball, step on the board with two feet at the same time, then quickly leave the ground with the right foot and dribble to the left. (3) In-situ pro-hop, Without accelerating, catch the ball from the ready position, then quickly leave the ground and dribble to the left. (4) Two-footed pro-hop, Accelerate from the ready position and catch the ball with two feet at the same time, then quickly leave the ground and dribble to the left. After catching the ball from the ready position, step on the plate with two feet at the same time, then quickly remove the right foot from the ground and dribble the ball to the left to complete the movement. In order to avoid the effects of handling sequence and fatigue on the participants, three different movement sequences were decided by drawing lots, including the two-footed step, the one-footed step and the in-situ step. The participants stood in the ready position before the experiment started and started the movement after the instructor's command.

4.2.2 Experimental procedures

This study draws on the statistical findings of C.Y.Bao [6] based on big data from professional basketball games (NBA, CBA, etc.) that the catch-and-cut action is immediate and cuts more to the left than to the right. The design of this experiment required all sample subjects to cut in the left direction, using the right foot as the non-axial foot and cutting 45 degrees to the left. After the subjects had warmed up, EMG slices were attached to the middle section of the rectus femoris and biceps femoris. To facilitate standardisation of EMG signals and comparison between modalities, reference was made to J.H.Li [7] Before the experiment, participants were tested unassisted for maximum voluntary isometric contraction (MVIC) and maximum isometric muscle force was collected for 5 seconds with 1 minute rest between each movement. At the end of the maximal muscle strength test, 45 reflective spheres were attached to the body as per W.X.Dai [8].

4.2.3 Data collection

The kinematic parameters were collected using a motion analysis system (ViconMX13+, Oxford Metrics Ltd., Oxford, England) for 3D motion capture at 200Hz, two force plates were used to monitor kinetic parameters at 1000Hz,meanwhile EMG signals were collected using a wireless surface EMG instrument at 1500Hz. Data were intercepted using a wireless surface EMG instrument at 1500 Hz.

(1) Kinematic parameters

The lower limb segments of the body are defined by the position of the reflective ball, including pelvis, thighs, calves and feet. The pelvis was defined by the left/right anterior superior spine and the left/right anterior superior iliac spine,the thigh was defined by the left/right greater trochanter, the left/right lateral femoral condyle and the left/right medial femoral condyle, the lower leg was defined by the left/right lateral femoral condyle, the left/right medial femoral condyle, the left/right lateral tibial condyle and the left and right medial tibial condyles. The hip joint centre was defined using the calculation of H.T.L iu[9] , i.e. the midpoint of the medial and lateral femoral condyles was then the knee joint centre, and the midpoint of the medial and lateral condyles of the tibial femur was the ankle joint centre. The origin of the thigh coordinate system is the hip centre, the X-axis is the link from the hip centre to the greater trochanter, the Z-axis is the link from the knee centre to the hip centre and the Y-axis is the direction of the product of the X- and Z-axes. The origin of the lower leg coordinate system is the centre of the knee, the X-axis is the link between the centre of the knee and the lateral femoral condyle, the Z-axis is the link between the centre of the ankle and the centre of the knee, and the Y-axis is the direction of the outer product of the X- and Z-axes. Knee flexion is defined as positive and extension as negative, internal rotation is defined as positive and external rotation as negative, internal rotation is defined as positive and external rotation is defined as negative. The trajectory of the reflective sphere in space was processed using Visual3D (C-Motion, Rockville, MD, USA) and filtered for noise with an 8 Hz low-pass filter. The force plate data was used to determine the non-axial foot landing period and the total length of the non-axial foot landing period was used as 100% to normalise the movement time as a percentage.

(2) Kinetic parameters

Force plate data were filtered using a low-pass filter at 50 Hz for the filtering action [10] , kinetics all parameters.The total time to landing was normalised as a percentage and the inverse dynamics was calculated using Visual3D.

(3) Electromyographic parameters

The raw data were analyzed using DasyLab 6.0 (measX, Germany) signal analysis software with a band of 10 to 400 Hz.A low-pass filter with a cut-off frequency of 10 Hz was used for smoothing to

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obtain a linear packet of myoelectric signals. Performing.The integrated EMG is obtained after the integration procedure and finally normalised with the EMG amplitude of the MVIC. StandardisationThe ratio of the post-activation signal of the rectus femoris divided by the activation signal of the biceps femoris is used as the co-contraction ratio.

4.3 Numerical and statistical method

In the course of the actual test, among the three repetitions of the same movement pattern, the highest peak ground reaction force was taken from the single performance.For statistical analysis of the data, which included knee joint angles, moments, forces and co-contraction ratios. Using Microsoft SPSS 21.0 Sociological Statistical Package, one-way analysis of variance by sample (oneway ANOVA), significance level set at $\alpha = .05$ if up to statistically significant differences, then post-hoc comparisons were made using the LSD method.

5. Results and analysis

5.1 Change in knee angle during the non-axial foot landing phase

The peak angle and time of occurrence of the knee joint in each direction during the landing phase of the different pro-hop patterns of the movement technique in basketball is shown in Table 1,Maximum angle of knee flexion in each direction during the landing phase of the right foot and the non-axial foot in different modes and its immediate onset A comparative analysis of raw time revealed that the peak angle of flexion in the one foot pro-hop was less than that in the in situ pro-hop and the two feet pro-hop, and was statistically,The peak valgus angle was greater and statistically significant ($p<0.05$) in the two feeted pro-hop than in the one footed pro-hop,Significantly different ($p<0.05$), peak internal rotation angle was statistically greater for the two feeted pro-hop than for the one footed pro-hop versus the in situ pro-hop Significantly different ($p<0.05$).

Table 1: Comparison of peak knee angles in each direction and time of onset during the non-axial foot landing phase

	Action mode	Time of occurrence	Maximum angle (degrees)
Internal rotation (+)/External rotation (-)	One foot	14.3±15.9*	24.84±7.79
	two feet	4.6±8.40**	27.85±7.40**
	In situ	25.1±17.3*	25.07±7.34
Extension (+)/flexion (-)	One foot	-53.36±6.16*	-54.36±6.16*
	two feet	-56.38±6.65*	-56.38±6.68*
	In situ	-50.28±8.13**	-50.29±8.15**
Inverted (+)/Extruded (+)	One foot	-14.95±4.90*	-14.96±4.91*
	two feet	-16.61±5.55*	-16.63±5.57*
	In situ	-15.51±6.81	-15.54±6.81

Note, * represents a significant difference ($p<0.05$), ** represents a highly significant difference ($p<0.01$)

5.2 Knee moment changes during the non-axial foot landing phase

Table 2: Comparison of peak moments and onset times for each direction of the knee joint during the non-axial foot landing phase

Direction of torque	Action mode	Maximum torque (Nm/Kg)	Time of occurrence (%)
Internal rotation (+)/External rotation (-)	**One foot**	0.11±0.03**	14.7±6.3
	two feet	-0.03±0.20*	27.1±8.2
	In situ	0.04±0.01*	14.5±5.7
Extension (+)/flexion (-)	**One foot**	2.81±0.48*	32.2±6.9*
	two feet	2.01±1.03*	32.9±14.5
	In situ	2.45±0.76	39.3±6.4*
Inverted (+)/External (-)	**One foot**	2.87±0.64	26.7±9.7**
	two feet	2.90±1.33	20.1±7.6**
	In situ	2.70±0.77	36.2±9.4**

Note, * represents a significant difference ($p<0.05$), ** represents a highly significant difference ($p<0.01$)

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The peak moments of the knee joint in each direction during the landing phase of the different pro-hop patterns for the movement technique in basketball are shown in Table 2, Maximum moments in each direction of the knee joint during the landing phase of the right foot and the non-axial foot in different modes and their immediate occurrence Comparative analysis of time reveals that the direction of the knee moment is dominated by extension, internal rotation and external rotation during the landing phase of the non-axial foot.In terms of moment in the transverse plane, the one footged step is greater than the double-legged step and the in-situ step, and is statistically significantly different($p<0.05$).

5.3 Angle of the knee joint at maximum moment generation

The joint angles between the peak knee moments during the landing phase of the different pro-hop patterns for the movement technique in basketball are shown in Table 3.A comparative analysis of the joint angles of the peak knee moments in different profiles during the landing phase of the right foot and non-axial foot in different modal situations revealed that when the forces in the direction of internal rotation tended to peak, the knee flexion was greater in the two feet and in situ pro-hop than in the one foot pro-hop, and was statistically significantly different ($p<0.05$), the valgus angle in the one foot pro-hop was less than in the two feet pro-hop, and was statistically significantly different ($p<0.05$).

Table 3: Joint angles between peak knee moments in different profiles

Maximum torque direction	**Action mode**	**Angular orientation**		
		Extension (+)/flexion (-)	**Inverted (+)/External (-)**	**Internal rotation (+)/External rotation (-)**
At maximum internal turning moment	**One foot**	0.11±0.03**	14.7±6.3	19.51±7.01
	two feet	-0.03±0.20*	27.1±8.2	17.42±8.74*
	In situ	0.04±0.01*	14.5±5.7	20.90±7.49*
At maximum extension torque	**One foot**	2.81±0.48*	32.2±6.9*	18.67±6.89*
	two feet	2.01±1.03*	32.9±14.5	17.28±7.09*
	In situ	2.45±0.76	39.3±6.4*	21.30±7.38**
At maximum internal rotational torque	**One foot**	2.87±0.64	26.7±9.7**	20.42±2.29
	two feet	2.90±1.33	20.1±7.6**	21.75±2.40
	In situ	2.70±0.77	36.2±9.4**	20.11±2.01

Note,* represents a significant difference ($p<0.05$),** represents a highly significant difference ($p<0.01$)

5.4 Ratio of co-contraction of the rectus femoris and biceps femoris during the landing phase

Ratio of co-contraction of the rectus femoris to the biceps femoris during the landing phase of the different pro-hop patterns of the movement technique in basketball (The electromyogram of biceps femoris is the denominator and that of rectus femoris is the molecule)are shown in Table 4.A comparison of the co-contraction ratios of the rectus femoris and biceps femoris during the right foot and non-axial foot landing phases in different patterns revealed that the joint angle descriptions of the peak knee moments in different profiles during the right foot and non-axial foot landing phases in different patterns revealed that the co-contraction ratios of the rectus femoris and biceps femoris activated by the single and two feet pro-hop were the ratio of co-contraction of the rectus femoris to the biceps femoris was greater than in the in situ step and was statistically significantly different.

Table 4: Ratio of co-contraction of rectus femoris and biceps femoris during the landing phase

One foot	**Two feet**	**In situ**
1.413*	1.831*	1.001**

Note,* represents a significant difference ($p<0.05$),** represents a highly significant difference ($p<0.01$)

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6. Discussion

6.1 Definition of knee landing risk periods and identification of factors

6.1.1 High and low risk periods for non-axle feet during the pro-hop landing phase

The ACL is primarily used to stabilise the knee joint to cushion the internal rotation and forward displacement of the tibia in relation to the femur. When the knee is flexed at an angle of less than 45 degrees, activation of the quadriceps muscle will tighten the ACL. An extended knee with excessive internal rotational torque, high valgus and valgus torque can easily cause ACL injury. Numerous empirical studies have found that the first 20% and last 70% of the pro-hop phase will have a flexion angle of less than 45 degrees, especially during the first 20% of the landing phase, which is accompanied by near-peak internal rotation angles, increasing the risk of ACL injury to some extent. For example, Zhang.M.Z (2017)[11] investigated ACL injuries over 12 seasons in the CBA league and found that internal or external rotation of the tibia is highly likely to lead to non-contact ACL injuries when the knee is near full extension and valgus. In a study by Liu, H. (2016)[12] , the approximate range of knee flexion and valgus angles during the cut-in manoeuvre were consistent with pre-landing kinematics and kinetics, and the pre-landing period was a highly sensitive risk period for ACL injury.

6.1.2 Non-axial foot risk constraints during the pro-hop landing phase

The factors influencing the risk of non-axial foot during the pro-hop landing phase are, in order of importance, (1) valgus angle. Previous literature has identified abnormal knee valgus angle from a frontal plane perspective as a significant factor in non-contact ACL injuries in female athletes. Combined with the three pro-hop patterns in this study, it is easy to see that the double-legged pro-hop has a larger peak valgus angle, the knee flexion angle in the double-legged pro-hop is already greater than 45 degrees, and at this flexion angle, the quadriceps pulls less on the ACL, relatively reducing the risk of ACL injury. (2) Valgus moment. The valgus moment is another important factor in predicting non-contact ACL injury. Previous studies have found that the axial foot is prone to generating an external rotation moment at an external rotation angle early in the deceleration phase, resulting in a non-contact ACL injury. In this study, the non-axial foot produced a degree of inversion moment during the landing phase in all three pro-hop modes, and the inversion moment reduced the valgus angle and prevented sustained knee valgus. It is assumed that the landing load on the non-axial foot is more likely to be less than that on the axial foot. (3) Flexion moment. The knee produces the only flexion moment during the first 10% of the landing phase, when the muscles around the knee produce an extension moment to counteract the passive moment, thus increasing tibial shear and ACL loading. (4) Internal rotation moment. In particular, the peak maximum internal rotation moment of the one foot pro-hop is more likely to cause a higher risk of ACL injury than the other two types of pro-hop, as shown in Table 2.

In summary, the findings of the literature are consistent with this study's view that the early phase of the non-axial foot landing phase is the most likely window for ACL injuries to occur, which makes it more valuable to discuss the clinical and practical prevention of internal ACL injuries in the first 20% of the landing phase. The kinematic and kinetic parameters such as valgus angle, valgus moment, flexion moment and internal rotation moment are used to interpret the risk of knee injury in the non-axial foot of the pro-hop.

6.2 Assessment and functional role of synchronisation of periarticular muscle activation

Muscle co-contraction means that the central nervous system automatically regulates the resistance of the peri-articular muscles to prevent excessive force from causing injury and to protect the stability of the joint, the strength of the peri-articular muscles being influenced by the position, displacement, speed and the force and torque generated by the joint. In contrast to the cut start of a running movement, the muscles around the knee are more activated during pre-contraction prior to landing or during landing in order to resist the higher internal and external rotation moments. The co-contraction ratio has been commonly used to evaluate the synchronisation of contraction and diastole between the muscles of the joints. For example, in a study by Zhang.J. (2016)[13] , it was found that the rectus femoris and biceps femoris had a high degree of co-contraction during the vertical jump, and the co-contraction ratio can be used to effectively observe the consistency of contraction between the muscles of the joints. In this study, the co-contraction ratio of rectus femoris to biceps femoris was found to be greater in the single- and double-legged pro-hop than in the in situ pro-hop, and the ratio was close to 1. The degree of contraction of the rectus femoris and biceps femoris around the knee joint in the in situ pro-hop mode was more consistent in the non-axial foot, which somewhat circumvented the increase in knee shear caused by

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over-activation of the rectus femoris, the co-contraction ratio of the posterior leg muscles was lower in the double- and one footged pro-hop, and they were relatively under-protected. Scientific training can improve the state of muscle activation to a certain extent, allowing the co-contraction of flexion and extension muscles to be synchronised and coordinated, thus reducing the risk of muscle strain or joint ligament injury.

7. Conclusion

The pro-hopded step followed by the non-axial foot launch technique in basketball footwork can lead to cruciate ligament injuries in the knee, particularly during the 20% of the landing phase. Based on the constraints of the knee landing risk factors, i.e. the angle of the knee during the non-axial foot landing phase, the joint moment, the angle at maximum moment, and the co-contraction ratio between the rectus femoris and biceps femoris, it was found that the one-footed pro-hoptep placed the greatest mechanical load on the knee during the non-axial foot landing initiation phase and was more likely to cause injury than the other two pro-hoptep patterns.

The statistical description and speculative conclusions of this study found that, based on the comparison of the non-axial foot movement patterns and biomechanical characteristics of different levels of basketball players in the pro-hop landing phase, the technical quality of the non-axial foot landing power movement after the three different pro-hop is constantly standardised, the technical completion level is improved and the pro-hop movement technique is reasonably chosen according to the game scenario, so that both the left and right foot can be used as the non-axial foot pro-hop start. At the same time, try to use the double-footed pro-hop followed by a random and skilled switch between the left and right foot as a non-axial foot pro-hop to avoid overloading the knee joint and lower limb on one side.

The knee joint, as an important joint tissue for human displacement, is increasingly critical and vulnerable in basketball, where frequent stops and restarts and speed changes are the main characteristics of movement. The toughness and strength of the ligaments, muscles and other hoof tissues that encase the knee joint provide the most basic protection for the joint's strength support, transmission mediation and force stress. Strengthening the overall strength of the ligaments and muscles around the joint, including the knee, taking into account the resistance of the large and small muscle groups, the deep and superficial surfaces, and the anterior and posterior confrontations will prevent and mitigate sports injuries to the greatest extent possible, improve performance levels and prolong the life span of the sport.

8. Research gaps and recommendations

8.1 Insufficient research

The experimental design of this study tends to maximise the performance of kinematic and kinetic parameters such as moment, angle and muscle ratio of the non-axial foot during the pro-hopded landing phase of a basketball game. The objective, realistic and efficient nature of such studies.

8.2 Recommendations

Scientific knowledge of the kinematic and kinetic characteristics of the non-axial foot force of different basketball pro-hop + post-start cuts, clarification of the probability of and constraints on the risk of injury from pro-hop and movement techniques, strengthening of the ligaments and muscle groups (front and back, size and depth) around the knee joint, standardisation and mastery of the movement quality of different basketball pro-hop + post-start cuts, so that the knee joint is supported, mediated and stressed by the force. The different types of offensive and defensive pro-hop and post-start cuts are selected according to the training scenario to reduce and share the load on the unilateral knee joint and other lower limb organs.

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