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Original Article

Kinematic assessment of the vertical jump in young basketball players

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Abstract
Problem statement Jumping is a Fundamental Movement Skill and a milestone for motor development. It is well known that this performance relates to the features of the considered population. In the sport practice, the jump is a component to assess physical abilities. Furthermore, basketball players are exposed to many injuries because of the jump rate, such as ankle or knee sprains. ***Approach*** Sixty young basketball players aged between 8.3 and 12.6 years (37 males, 23 females) participated in this study. An ecologic assessment protocol to investigate the specific vertical jump pattern of this sample was set up in the basketball gyms. An anamnestic questionnaire, BMI, and kinematic assessment were used. ***Purpose*** The aim of this cross-sectional study is to describe the specific kinematic jumping pattern in young basketball players. ***Results*** Data support the importance of a child-specific kinematics analysis of the vertical jump. The lower quadriceps strength and the larger flexibility of ankles in children justify the large involvement of this joint during the vertical jump (down 25.3°, up 24.1°, flight 7.4°, landing 26.4°). Multiple linear regression demonstrates that the movement of the hip during flight is significantly influenced by age (p-value=0.04), especially in males (p-value=0.02). In addition, the movement of the knee during flight is significantly related to BMI in males (p-value=0.01). ***Conclusions*** New data about the specific jumping pattern of young basketball players are provided to create adapted and appropriated prevention protocols. Young basketball players show a specific immature motor pattern during the vertical jump.
Keywords: Motor skills; Hop; Biomechanics; Children; Sport.

Introduction

Jumping is a milestone for motor development. It makes up part of the locomotor Fundamental Movement Skills[1]commonly developed in childhood and consequently refined through a specific sport practice[2].Evidence suggests that jump performance varies within the population, yet normative data are needed[3], especially for children.

The vertical jump is also a component toassess physical ability[4] and peak leg power[5]. Basketball athletes of all ages need to win airchallenges,and jumping ability is necessary to improve performance[6]. Moreover, basketball has a high jump rate and is considered a high-risk sport for injuries, such as knee or ankle sprains[7 8 9]. In the field of physical activity, the study of cognitive functioning[10 11] and of the posture[12] of young basketball players has developed recent evidence. Nevertheless, there is little evidence about jumping kinematics in this population. Because of different motor patterns between children and adults[2 13], the literature supports the importance of an integrated injury prevention program strictly considering the age-band[14]. Recently, Swartz and colleagues (2005)[15] found thatchildren utilize a different jump strategy from adults. They affirm that children's knees have a bigger valgus angle than do those of adults, and the hips and knees are more extended and stiff during the landing. Moreover, Schiltz and colleagues (2009)[16] gave an example of the influence of sport practice on jump abilities depending on the level and on the age of training. Meylan and colleagues (2012)[6] examined the jump kinetics and kinematics in athletes aged from 9 to 16 years. Their aim was to verify the reliability of concentric and eccentric kinematics and kineticsas indicators of jump and stretch-shortening cycle performance. The authors focusedon the force analysis of muscular efficiency. Our study aims to enrich the evidenceof the kinematicsof the jump in the specific population of young basketball players to increaseknowledge and to create a proper prevention protocol for them. The innovation of our approach is that we introduce the assessment of the jump of a specific young population in terms of joint ranges of motion.

Materials and Methods

Design

This cross-sectional studyinvestigated the prevalence of a specific jumping pattern in an analytic sample of young basketball players. We conducted the full evaluation during 4 weeks of the basketball season 2017–2018. After data analysis, we gave individual reports to the coaching staff and to the parents. The institutional ethics committee approved this study. The parents and the children read and signed the informed consent before starting study participation.

Participants

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Four basketball clubs agreed to participate in this study. Sixtybasketball players aged between 8.3 and 12.6 years were assessed(Table I). Males and females wereevaluated together, because in this age-band, they play basketball together and there are no gender differences in the games. The inclusion criteria wereto be between 8 and 12 years old and to practice basketball at least 3 times a week for at least 2 years.

Table I. Children's characteristics

n=60	Male=37	Female=23	
	Mean (SD)	Max	Min
Age (years)	10.48 (1.09)	12.58	8.31
BMI	18.19 (3.15)	33.25	13.60

Procedures

Assessments were performed through an ecologicapproach during practice in the basketball gym. According to the coaches, one player exited from the play to be assessed. The assessment was approximately 10 minutes long and required three trials. After each jump, there were pauses of 30". Each child freely chose the starting position of the feet, andwe registered it on the floor with tape. In addition, all the players received the following recommendations: (1) jump as high as possible, (2) imagine the obstacle of another player, (3) put your hands on your hip (to eliminate the bias of upper limb strength during the jump), and (4) do not move after landing.

Anamnesis

We used a specific questionnaire (filled by the parents) to record personal data and injury history, especially in relation toknee and ankle strains. We also measured body mass and height.

Kinematic Assessment

We assessed the vertical jump in its four phases: down-phase, up-phase, flight, and landing[17]. To assess the kinematics of the vertical jump, we used the digital technology MtwAwinda Development kit-ii®,whose reliability was supported bythe previous literature[18]. This wireless portable system consists of accelerometers, magnetometers, gyroscopes, barometers, and thermometers performing at a sampling frequency of 1,000 Hz. We applied the sensors to the dominant leg of each player in the following key-points: above the iliac crest (lateral), 8 cm above the knee's articular line on the femur (lateral), 8 cm below the knee's articular line on the fibula on the foot (lateral), on the talus (dorsal), and on the belly button (frontal, as projection of the barycentre). To collect the data, we used the MT Manager Softwarethat allowsthe verification of real-time 3D orientation and the assessment of the inertial and magnetic forces of the sensors. During the detection of the movements, the software provides a graphic representation of the following Euler's angles: yaw (direction of the sensor, which rotates on the Z-axis [-180°, 180°]), pitch (elevation and inclination of the sensor, which rotates on the Y-axis [-90°, 90°]), and roll (rotation of the sensor, which rotates on the X-axis after the second rotation [-180°, 180°]). In this study, we considered the relative angles of the joints. No absolute values of the limbs' position were measured and used. Because we were looking for relative values, the emerging measures did not need a previous calibration.

Statistical analysis

We provided descriptive data about one vertical jump for each subject. Through the software, we chose the more balanced jump, where the barycentre sensor produced fewer after-landingoscillations.Data were analyzed using proprietary software written in MATLAB (Matrix Laboratory)[19]. After data normalization, multiple linear regressions were ran to estimate the association between the joint ranges of motion during the jump and the following independent variables: age, gender, and BMI; p-value stepwise was employed to assess the associations. Interactions were retained if the magnitude of the interaction effect was of potential statistical significance, set at $p<0.05$.

Results

Table IIshows the data description of the joint kinematics of the entire sample during the four phases.

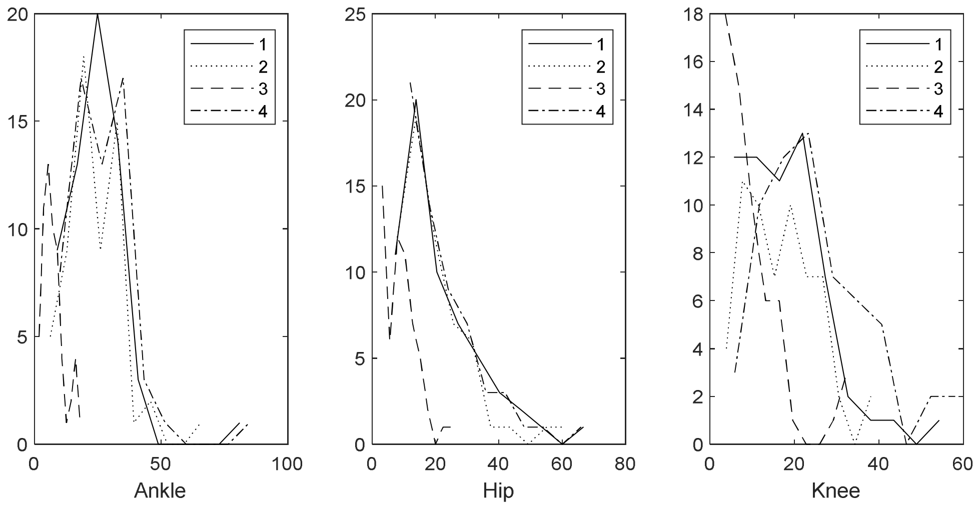
Table II. Joint kinematics in the different phases

	Mean (SD)	Max	Min
	Down phase		
Hip	21.0° (13.6°)	70°	4°
Knee	18.0° (10.2°)	57°	3°
Ankle	25.3° (12.3°)	85°	5°
	Up phase		
Hip	19.0° (11.4°)	66°	5°
Knee	16.4° (8.7°)	40°	2°
Ankle	24.1° (11.0°)	69°	3°
	Flight		
Hip	9.0° (5.2°)	26°	2°
Knee	9.9° (7.3°)	34°	1°
Ankle	7.4° (4.2°)	16°	3°
	Landing		
Hip	22.5° (12.0°)	69°	9°
Knee	24.5° (12.7°)	61°	3°
Ankle	26.4° (12.5°)	89°	6°

° Values expressed in degrees. The data express a range of motion. Mean=mean range of motion; SD=standard deviation; Max=maximal value; Min=minimal value.

Figure 1shows the sample distribution during the four phases of the vertical jump: down, up, flight, and landing.

Figure 1. Sample distribution during the vertical

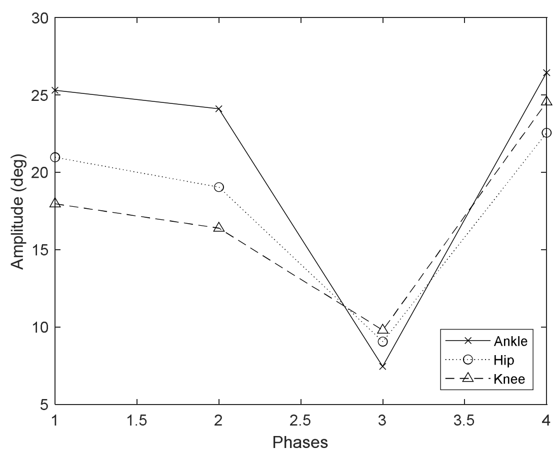


jump

x-axis= joint angle; y-axis= number of subjects; 1=down phase, 2=up phase, 3=flight, 4=landing.

Figure 2 summarizes the mean-values calculated on the complete sample, by considering the motion of the three joints during the four phases of the vertical jump.

Figure 2. Meanrange of motion during the vertical jump



1=down phase, 2=up phase, 3=flight, 4=landing.

Table III shows the significant results of multiple linear regression analysis. By considering the complete sample, the movement of the hip during flight is associated withthe age of the subject (5%); in males, this association increases (9%). The movement of the knee during flight is linked to BMI, but onlyin the male sample (15%). We found no association by separately considering the female sample.

Table III. R-squared coefficient and standard error for the three linear regression models, showing a significant relation among age, BMI, andhip/knee flight angles

Sample	Dependent/Independent Variable	R^2	SE	p-value
Full sample (n=60)	Hip flight/Age	0.05	0.39–0.19	0.04*
Malesonly (n=37)	Hip flight/Age	0.09	0.61–0.25	0.02*
Males only (n=37)	Knee flight/BMI	0.15	(-)0.80–0.30	0.01**

R^2=adjusted coefficient of determination; SE= standard error

Discussion

The anamnestic questionnaire provided data about personal and history injury, which allowed us to consider the entire sample. The kinematic assessment allowed us to describe the prevalent pattern of motion of young basketball players' vertical jump. Most relevant information comes from the qualitative assessment of the joints, which demonstrates some peculiarities in this sample.

The present literature supports the importance of a child-specific kinematics analysis of the vertical jump. Figure 1 and Figure 2 demonstrate the larger use of the ankle—in terms of range of motion—compared to the other involved joints. The lower quadriceps strength and the larger flexibility of children's ankles (Holt et al., 2009)[20] support this result. From the merging data, the observed children seem to use trunk and ankle strategies to increase strength in the down phase. This data agrees with Dotan et al.'s evidence[13], which supports the differences between adults and children in many muscular performances.

Even if the sample consists of sporty, healthy children and young adolescents, the differences with adults' vertical jump are many. Considering Bobbert'sevidenceconcerning adults[21 22 23], our qualitative assessment confirms the importance of separating children's and adult's performances. In fact, the younger population significantly reduces the range of motion of the hip, knee, and ankle. For instance,during the down phase,in the adult,the hip flexes 80.21°, while our sample flexes 20.97°. In this phase, the same large difference exists for knees (adults=97.40°, children=17.96°) and ankles (adults=85.94°, children=25.30°). These data demonstrate an immature motor pattern in children; instead of flexing the quadriceps, they absorb energy from the gastrocnemius and plantar flexor during the beginning dorsiflexion[24].

Our results show that during the last phase, the hip flexes 22.55°, the knee 24.53°, and the ankle dorsal 26.43°. These data demonstrate that during the landing,the children flex more than in all the other phases. We can explicate this outcome considering the elasticity and muscular attitude of the children. In fact, the outcomes suggest that they are unable to amortize the charge of the jump with the muscle strength, so they reach large extension ranges, especially with flexible ankles[25]. The previous data agree with the study of Horitaet al.[26], affirming that compared to adults, children do notexhibita mature pattern of movement during the preparatory and flight phases.In terms of motor learning and injury prevention, children have motor peculiarities in the vertical jump[27 28], well known asa risk factor for ankle and knee sprains[29].

Multiple linear regression weakly supports the association between age and motor pattern; however, the movement of the hip duringflight seems influenced by age ($p=0.04$), especially in males ($p=0.02$). In addition, the movement of the knee during flight is related to BMI in males ($p=0.01$). This result is supported by the present literature, where normal and overweight children demonstrate different motor competences, even in the vertical jump[30]. To understand these data better, increasing the sample is necessary. Nevertheless, these results confirm the importance of consideringthe peculiarities of children when creating prevention and rehabilitation programs; according to the literature, even between childhood and adolescence, there are already significant differences to consider during the professional take in care[2 14].

In the current study, the kinematic assessment doesnot provide data about the joint ranges of motion on the frontal plane. Because of the software setting, we were unable to assess the valgus attitude of the knee during the jump; this is the main limitation of the current study. Nevertheless, our study adds to the literature new information about the specific jumping pattern of young basketball players.

Conclusions

Our finding supports that young basketball players show a specific immature motor pattern during the vertical jump. To create prevention programs, as professionals, we should consider their specific motor scheme. Accounting for the peculiarities of this motor pattern shall be the starting point to build coherent, appropriate training for this sample.
During the vertical jump, the significant work of the ankle and the particular activation of the hip are important clues to consider. The inability to provide a mature amortization during the landing should be the key point to create a focusedprevention program. Our results demonstrate that each professional and coach should consider the physical differences between older and younger players to offeractivities that are as riskless as possible and to strengthen the specific weakness points. The present study provides a sustainable tool to collect replicable data in an ecological assessment setting.

Conflict of interest - There is no actual or potential conflict of interest in relation to this article.

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