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ชีวกลศาสตร์ทางการกีฬา (Sports Biomechanics)

EFFECT OF HURDLE HEIGHTS ON JUMPING MECHANICS IN YOUTH MALE SOCCER PLAYERS

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ABSTRACT

The purpose of this study was to investigate the effects of bilateral hurdle jump on jumping mechanics in adolescent male soccer players including contact time (CT), peak vertical ground reaction force (PVGRF), rate of eccentric force development (E-RFD) and lower extremity stiffness (LS). Fifteen male soccer players (mean age 13.93 ± 0.25 years) participated in the study. Subjects performed hurdle jumps continuously over 4 hurdles with the force platform positioned between the second and the third hurdles. Four different hurdle height conditions (100%, 120%, 140% and 160% of the maximum countermovement jump heights) were compared. One-way repeated-measure ANOVA did not revealed any statistically significant differences among CT, PVGRF and E-RFD at any hurdle height conditions. However, LS of 160% hurdle jump was significantly greater than those of 100% and 140% hurdle jumps ($p < 0.05$). In conclusion, the results suggest that hurdle jump at 100-140% of CMJ (range: 30 - 42 cm) of CMJ may be an optimal height for training in adolescent soccer players. Additionally, prescribing repeated hurdle jump at 160% of CMJ may need a great care since it has the greatest lower extremity stiffness which may increase the risk of lower extremity injury.

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KEYWORDS: ground reaction force, hurdle jump, stretch shortening cycle, soccer, youth

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INTRODUCTION

Soccer is an intermittent sport which highly demands on physiological, technical, and tactical skills during a 90 minute competition[1, 2] Plyometric training is commonly used for developing explosive power in soccer players. The key of this type of training is based on eccentric muscle contraction immediately followed by concentric contraction.[3] Recently, the number of participants engaging in soccer, especially who are younger than 18 years, has dramatically increased. Although a variety of factors have been proposed to be risk factors of injury, growth-related factors, training workload and conditioning levels are among major risk factors of overuse injury in adolescents or youths training for sport competition[4] Hurdle jump is one of plyometric training drill, which its intensity can be modified by adjusting the hurdle height, increasing the number of hurdles, and varies the pattern of jump. Previous studies have determined the varieties of hurdle height for general population and adult athletes. A hurdle height between 30 - 90 cm. has been recommended for general practice which the range between 30 - 40 cm and 50 - 60 cm have been commonly used for training in adult male soccer players and volleyball players, respectively.[5] Additionally, improvements of leg power, jump and sprint performances have been reported after training in young soccer players by incorporating the hurdle jump height starting from 40 cm and progressively increased to 60 cm.[6] In contrast, with similar hurdle heights training, no significant change on muscle power after training was observed in male physical education students.[7] However, increasing height of the hurdle can prolong contact time (CT), negatively affect rate of muscle contraction,[8] and increase lower extremity stiffness which tended to increase risk of bony injuries.[9] Therefore, training drills or programs commonly used in adult may not be relevant for adolescent players. To the author's knowledge, no previous researches report the appropriate hurdle height regarding to mechanics of hurdle jump in adolescent male soccer players. Therefore, the purpose of this study was to investigate the effects of different hurdle heights in adolescent male soccer players in terms of jumping mechanics including contact time (CT), peak vertical ground reaction force (PVGRF), rate of eccentric force development (E-RFD) and lower extremity stiffness (LS). We hypothesized that levels of hurdle height could affect the mechanic variables of jumps differently.

METHODS

Experimental Approach to the Problem

A randomized repeated measures experimental design was used to test the hypothesis that variations of hurdle height affect jump performance differently. The independent variables in this study were different hurdle heights whereas the dependent variables were CT, PVGRF, E-RFD and LS.

Subjects

Fifteen healthy adolescent male soccer players; mean ± *SD*; age 13.9 ± 0.3 years, weight 54.5 ± 7.8 kg, height 165.7 ± 6.5 cm, %body fat 7.54 ± 4.2%, volunteered to participate in this study. Subjects received

strength training for at least 3 month prior to the beginning of study. They were excluded from the study if they had lower extremity musculoskeletal injuries. All

subjects signed an informed consent before enrolling and all of the procedures were conducted in accordance with the declaration of Helsinki approved by Mahidol University Institutional Review Board (2013/098.0810).

Testing Procedures

Subjects visited the lab two times. The first visit was to determine the levels of hurdle height from CMJ. Prior to perform CMJ test, subjects were instructed to warm up by jogging for 5 minutes and then performed hopping and submaximal CMJ for 3x2 set. Three maximal CMJ were performed 3 times while subjects stood on the force platform. The highest height then used to define the height at 100%, 120%, 140% and 160% of the maximal CMJ. At the second visit, subjects were performed bilateral hurdle jumps forward over the hurdles 2 times. Before the test, subjects warmed up by jogging for 5 minutes and then double leg hopping and submaximal CMJ for 3x2 sets. The order of hurdle heights using for hurdle jump test was randomized. A minute rest between the jumps was provided to avoid fatigue. Subjects were allowed to swing arms in a natural position and were not received any specific instruction about the leg position or knee movement during the jump. Subjects jumped forward over 4 hurdles with the force platform position after the second. The distances between the hurdles were set at 60 centimeters apart.

Instrumentation

A force platform (OR6-5-2000, Kistler Inc., Switzerland) was collected ground reaction forces for both during taking off and landing. Ground reaction force data were collected at the sampling rate of 500 Hz and later were analysed with Bioware program (Kistler Inc., Switzerland). Contact time (CT) is length of time when the feet contact the ground, starting by time of foot contact on force platform to the departing of feet from force platform. Peak vertical GRF data occurred during the landings were obtained. The E-RFD was defined as the first peak of GRF divided by the time from onset of landing force to the first peak of GRF.[10] LS was obtained from peak vertical ground reaction force divided by the maximal vertical displacement of the center of mass during contact with the ground. The vertical displacement of the center of mass during contact determined from the difference between the maximum and minimum values of vertical force curve.[11]

Statistical analysis

The statistical analysis was undertaken using SPSS 17.0 for windows. Komogorov-Smirnov test was used to ensure normality of data. One-way repeated measures ANOVA was employed to determine significant main effect of hurdle heights on jump mechanic variables. When assumption of sphericity was not met, Huynd-Feldt correction was used. If significant main effect was found, Bonferroni pairwise comparison was used to identify which pairs of the hurdle heights were significantly different from each other. The level of significance was set at p-value less than 0.05.

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RESULTS

Although CT tended to increase with the progression of hurdle height ($F_{2.4,33.5} = 2.61$, $p = 0.08$), the highest CT was < 200 ms, and there was no significant difference of CT and the other jump mechanics parameters (PVGRF and E-RFD) between different hurdle heights conditions (Table 1 and Figure1). However, significant main effect of hurdle height on LS was observed ($F_{3,42} = 6.14$, $p < 0.01$) with differences between 100% *Vs.*160% bilateral jumps ($p < 0.01$), and between 140% *Vs.* 160% ($p < 0.01$) (Figure 2).

Table 1. Jump mechanics parameters between different heights

CT= contact time PVGRF= peak vertical ground reaction force E-RFD= rate of eccentric force development

% CMJ height	Hurdle height (cm)	CT (ms)	PVGRF (N)	E-RFD ($N.S^{-1}$)
100%	29.9 ± 3.5	175.5 ± 23.3	3,445.11 ± 608.8	48,398. ± 14,556
120%	35.8 ± 4.2	176.4 ± 20.3	3,480.67 ± 556.2	48,989 ± 12,368
140%	41.8 ± 4.8	183.3 ± 28.0	3,524.26 ± 608.3	52,191 ±18,959
160%	47.9 ± 5.5	196.3 ± 44.4	3,436.02 ± 725.0	48,787 ± 16,315

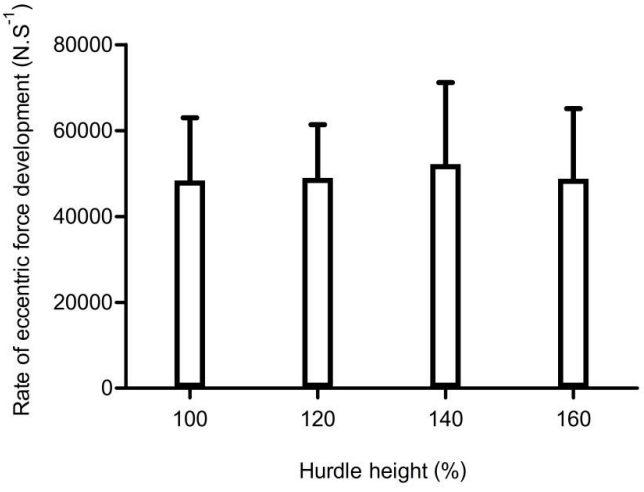

Figure1 Rate of eccentric force development (E-RFD) between different hurdle heights

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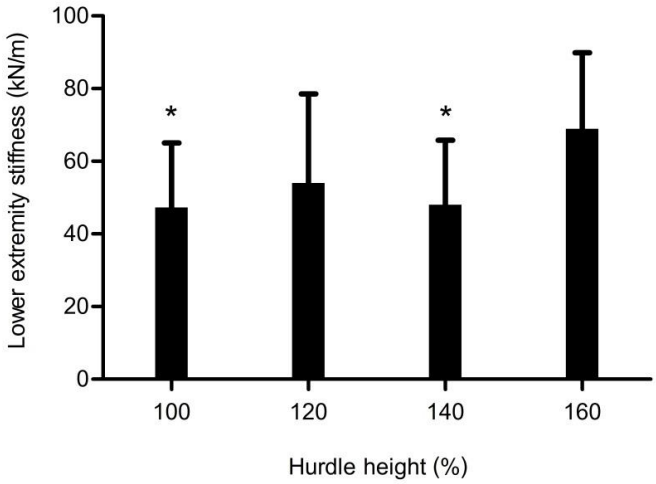

*Significant difference compared with 160% hurdle jump at p<0.05.

Figure 2. Lower extremity stiffness (LS) between different hurdle heights

DISCUSSION

The purpose of this study was to investigate the effects of different hurdle heights on jumping mechanics. Interestingly, we did not find any differences of CT, PVGRF and E-RFD between different hurdle heights conditions except the LS. CT of CMJ in this study was approximately 175 – 197 ms which is similar to CT of high jumping (175ms), first 3 steps from starting blocks (200, 180, and 160 ms) and high jump using flop technique (177 ms). When compared with CT of 160% bilateral from Cappa,[8] CT in this study was shorter. This might be the result of different jumping techniques e.g. free arm[8] Vs. non-free arm during CMJ test used for establishing the hurdle height, which can mainly affect the absolute value of CMJ height (100% CMJ), and, therefore, the other levels of hurdle heights. The non-free arm jumping during CMJ test in the current study is a fixed position with the hands on the hip in order to minimize the influences of the upper body. The difference between height of CMJ using free arm and non-free arm has been reported to be about 28% with a significantly higher in free arm jump. Additionally, free arm movements during jumping can lead to a higher peak total body center of mass (TBCM), peak vertical ground reaction force (PVGRF), peak positive power (PP), release velocity and, thereby, a greater jump height. Besides, distance between each hurdle may also affect jump mechanics. From pilot trial of the present study, the distance was set at 40 cm as previously reported.[8] However, the subjects were unable to jump over the hurdle set 40 cm apart without compromising their stability. Therefore, the distance between the hurdles was adjusted to 60 cm. Peak vertical ground reaction force (PVGRF) of the hurdle jumps were observed in the present study and PVGRF of 100% - 140% jump were about 3,400 – 3,500 N. The PVGRF of jump was lower than that reported by Cappa and Behm, 2011 (4,000 – 4,300 N).[8] Studies have shown that PVGRF increase with increasing body weight.[12] Therefore,

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the difference of PVGRF between the present study and the other[8] may be resulted from the different body weight between groups of subject. This can be clearly comparable if PVGRF were normalized relative to subject's body weight. Additionally, the lower PVGRF of hurdle jump compared to the other study could be the result of different absolute hurdle heights, jumping technique and jumping velocities. Generally, it has been suggested that the intensity of plyometric exercises are greater with higher PVGRF during single-leg jump or jump over a higher height[13] and there is high negative correlation between peak force and contact time in running.[14] However, the heights of hurdles in the present study have no effect on the PVGRF. Studies have suggested that a high amount of PVGRF value can increase risk of overuse injury of the lower extremities and being a potential cause of stress fracture. Increased landing times in order to decrease impact forces has been suggested to improve landing technique in sports e.g. basketball and baseball. However, in plyometric training, an increase in contact time may compromise muscle force and power. Therefore, type of plyometric activities and, especially, training intensity and volume must be considered to achieve optimal training effect and reduce risk of overuse injury. Rate of eccentric force development (E-RFD) has been defined as the rate of rise of contractile force at the beginning of a muscle action and is among the most important factors influencing performance in sports activity. No significant difference between each other bilateral E-RFD (48,000 – 52,000 N.S-1) was observed in the present study. These ERFD of bilateral hurdle jumps were relatively higher than those reported in the previous study (35,000 – 40,000 N.S-1)[8] but E-RFD tended to be decreased at 160% bilateral hurdle jump. Moreover, a decrease time to peak force has been suggested to associate with a higher ERFD. Lower extremity stiffness (LS) is a factor used to explain shock absorption mechanism. Shock absorption mechanism is the combination of muscles, tendon, ligament, cartilage and bone properties and functions during the landing phase. Additionally, the difference of LS between bilateral jump at lower levels of height and at 160% height were observed. Therefore, the results suggested that jump pattern/technique and the height of hurdle can possibly modulate lower extremity stiffness. Wang et al. (2009) and Arampatzis et al. (2001)'s studies supported that landing from increased height can increase peak vertical ground reaction force, loading rate and lower extremity stiffness (LS).[15, 16] Comparison to previous studies, LS during a lateral plant and reverse movement (49.02 ± 12.8 kN/m) and hopping were similar to LS of bilateral hurdle jumps at most of the height levels 100 – 140% bilateral jump (48 – 69 kN/m) in the present study except with the LS of 160% jump. In summary, although contact time tended to increase with progression of hurdle heights; set relative to jumping capacity of individual adolescent soccer players (%CMJ), especially at 160% bilateral hurdle jump compared to the other lower heights, hurdle heights had no effect on peak vertical ground reaction force (PVGRF) and rate of eccentric force development (E-RFD) of bilateral hurdle jumps, but potentially increased LS at 160% bilateral jump. Therefore, when balancing between performance and risk of injury, optimal height for bilateral hurdle jump should be in 100% - 140% height ranges.

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PRACTICAL APPLICATIONS

Hurdle jump is commonly used in plyometric exercise. Understanding the effect of hurdle height on jumping mechanic variables is important to allow practitioners to prescribe or progress plyometric exercise from low to high intensity over the course of a program. Appropriate hurdle height based on the level of player's CMJ performance and jumping mechanics examined in the present study provides the coach and athlete with means of quantifying plyometric exercises in addition to the athlete's weight and the height of the jump, etc.

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