THE RELATIONSHIP BETWEEN JUMPING AND SPRINTING PERFORMANCE IN TEENAGE SPRINTERS

RELAÇÃO ENTRE O DESEMPENHO DE SALTO E SPRINT EM VELOCISTAS ADOLESCENTES

RELACIÓN ENTRE EL DESEMPEÑO DEL SALTO Y EL SPRINT EN VELOCISTAS ADOLESCENTES

ORIGINAL ARTICLE
ARTIGO ORIGINAL
ARTÍCULO ORIGINAL

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ABSTRACT

Objectives: This study aimed to examine the relationship between vertical jumping at forces of specific time phase and sprint performance in teenage sprinters. Methods: Fifteen male teenage sprinters (age: 14±2 years, height: 168±2 cm, weight: 61±1 kg) participated in the study. The subjects performed the following bilateral/unilateral jumps on a force platform: a) squat jump (SJ), b) unilateral SJ (USJ), c) 40cm drop jump (DJ), and d) 20cm unilateral DJ (UDJ). The 60m sprint test was administered on the second day. Brower split timers were positioned to record subjects' 5m, 10m, 50m and 60m split times. The variables for inclusion were vertical jump height, maximum force, and force output at 120ms in all jumps and sprint time measures. Results: The results of the Pearson Product Moment Correlation analysis showed that SJ120ms was correlated to 5m and USJ120ms was correlated to 10m. UDJ120ms showed a stronger correlation with 50m than DJ120ms. Although significant correlations using maximum force and height were observed, there were inconsistent results between bilateral and unilateral jumps. Conclusion: Our results highlighted that jumps that have similar form with certain force outputs at specific event timing could more precisely predict sprint performance in teenage sprinters. USJ120ms and UDJ120ms could better predict the acceleration (10m) and high-speed phase (50m) in sprint performance, respectively. Moreover, coaches and practitioners should be cautious when using only jump height or maximum force to predict sprint performance, since the results could be inaccurate when specific movement variables are not thoughtfully considered. ***Level of Evidence III.***

Keyword: Acceleration; Athletic performances; Plyometric exercise.

RESUMO

Objetivos: Este estudo teve como objetivo examinar a relação entre o salto vertical e a força em tempo específico e o desempenho de sprint em velocistas adolescentes. Métodos: Quinze adolescentes velocistas do sexo masculino (idade: 14 ± 2 anos, estatura: 168 ± 2 cm, peso: 61 ± 1 kg) participaram do estudo. Os indivíduos realizaram os seguintes saltos bilaterais e unilaterais em uma plataforma de força: a) squat jump (SJ), b) SJ unilateral (USJ), c) drop jump (DJ) de 40 cm e d) DJ unilateral (UDJ) de 20cm. O teste de sprint de 60 m foi realizado no segundo dia. Os cronômetros rastreadores para treinos fracionados foram posicionados para registrar os tempos fracionados de 5 m, 10 m, 50 m e 60 m. As variáveis para inclusão foram altura do salto vertical, força máxima e saída de força a 120 m em todos os saltos e medidas de tempo do sprint. Resultados: Os resultados da análise da correlação produto-tempo de Pearson mostraram que o SJ de 120 m foi correlacionado com 5 m e USJ de 120 m foi correlacionado com 10 m. O UDJ de 120 m teve correlação mais forte com DJ de 50 m do que de 120 m. Embora tenham sido observadas correlações significativas com força e altura máximas, alguns resultados foram inconsistentes entre os saltos bilaterais e unilaterais. Conclusões: Nossos resultados destacaram que os saltos com forma semelhante a certas saídas de força no tempo específico do evento podem prever com mais precisão o desempenho no sprint em adolescentes velocistas. O USJ de 120 m e o UDJ de 120 m podem prever melhor, respectivamente, a aceleração (10 m) e a fase de alta velocidade (50 m) no desempenho no sprint. Além disso, treinadores e praticantes devem ser cautelosos ao usar apenas a altura do salto ou a força máxima para prever o desempenho no sprint, uma vez que os resultados podem ser imprecisos quando variáveis específicas do movimento não forem consideradas com precisão. ***Nível de evidência III.***.

Descritores: *Aceleração; Desempenho Atlético; Exercício pliométrico.*

RESUMEN

Objetivos: Este estudio tuvo como objetivo examinar la relación entre el salto vertical y la fuerza en tiempo específico y el desempeño del sprint en velocistas adolescentes. Métodos: Participaron en el estudio quince adolescentes varones velocistas (edades: 14 ± 2 años, estatura: 168 ± 2 cm, peso: 61 ± 1 kg). Los individuos realizaron los siguientes saltos bilaterales y unilaterales en una plataforma de fuerza: a) squat jump (SJ), b) SJ unilateral (USJ), c) drop jump (DJ) de 40 cm e d) DJ unilateral (UDJ) de 20 cm. La prueba de sprint de 60 m se realizó el segundo día. Los cronómetros en el entrenamiento fraccionado se ajustaron para registrar tiempos de 5 m, 10 m, 50 m y 60 m. Las variables que se incluyeron fueron la altura del salto vertical, la fuerza máxima y la salida de fuerza a 120 m en todos los saltos y mediciones del tiempo del sprint. Resultados: Los resultados del análisis de correlación producto-tiempo de Pearson

Editor Associado responsável pelo processo de revisão: Dartagnan Guedes

revelaron que el SJ de 120 m estaba correlacionado con 5 m y el USJ de 120 m estaba correlacionado con 10 m. El UDJ de 120 m tuvo una mayor correlación con el DJ de 50 m que con el de 120 m. Aunque se observaron correlaciones significativas con la fuerza y la altura máximas, algunos resultados fueron inconsistentes entre los saltos bilaterales y unilaterales. Conclusiones: Nuestros resultados pusieron de manifiesto que los saltos con una forma similar a determinadas salidas de fuerza en un tiempo específico del evento pueden predecir con mayor precisión el desempeño en el sprint en adolescentes velocistas. El USJ de 120 m y el UDJ de 120 m pueden predecir mejor, respectivamente, la aceleración (10 m) y la fase de alta velocidad (50 m) en el desempeño del sprint. Además, los entrenadores y practicantes deben ser cautelosos a la hora de utilizar únicamente la altura del salto o la fuerza máxima para predecir el desempeño en el sprint, ya que los resultados pueden ser inexactos cuando no se tienen en cuenta con precisión las variables específicas del movimiento. ***Nivel de evidencia IIIg.***

Descriptores: *Aceleración; Rendimiento atlético; Ejercicio pliométrico.*

DOI: http://dx.doi.org/10.1590/1517-8692202329022022_0010i Article received on 01/21/2022 accepted on 07/12/2022

INTRODUCTION

Performance of sprinting events relies on athletes' level of comprehensive fitness capacity. For years, researchers have attempted to apply time-saving laboratory examinations to identify strength-power capabilities related with sprinting. Among those tests, various forms of jumps were utilized and found to be associated with sprint performance and could be potential predictors of superior sprinting performance.[1-5] Some studies have identified certain factors that may be influential to the experimental results.

For sprinters, acceleration and maximum-velocity phases are vital in 100m performance and each phase has distinctive forms. In initial acceleration phase (5m), the movement is 81.1% concentric dominated in the first step,[6-8] and this logically would be more related to squat jump (SJ), which removes the stretch-shortening cycle (SSC) and assess purely on lower-body concentric power. After 5m to maximum velocity phase, the eccentric movement gradually increases and contact time becomes shorter,[6,8,9] and this would resemble drop jump (DJ), which requires pre-stretching of the lower limb musculature while contracting at a high velocity. However, the indications from the previous studies varied. Some research stated SJ height (SJH) and sprint acceleration performance were found to be related.[1,10-14] And drop jump height (DJH) was reported by researches to have positive relationship with maximal velocity (Vmax) in sprinters.[5,14,15] Yet, other studies have reported significant relationships between Vmax and SJ.[5,14-17] These results indicated other factors should be taken into consideration. For instance, many studies have tried to identify relationship between bilateral/unilateral jumps and sprinting. Sprinting is a single-leg alternative and a cyclic movement. Some believe unilateral jumps possess a higher level of predictivity and could be a better indicator than bilateral jumps because sprint impulse is developed during a unilateral stance phase.[18] Studies reported significant correlations between bilateral jumps and sprint performance (r= -0.52 to -0.77),[1,19] whereas conflicting results emerged when a few research including both unilateral and bilateral jumps in indicated stronger correlations in sprint performance with the unilateral jumps (r=-0.74 to -0.89).[11,20] Other studies discuss the rate of force development (RFD) in these jumps.[1] In general, it takes approximately 300ms to reach maximum force production in jumping, but in crucial moment of sport it may take less than 200ms sec.[21] The true meaning of RFD application would be different in each phase of sprint (acceleration to maximal speed). Rate of force development may better be described as the force in specific sports event. In 100m sprint, RFD in each phase is different among acceleration, transition, and maximal speed to maintenance. The stance time during acceleration phase could be vary from 0.86 - 0.17 sec, and between 0.09 - 0.11 sec during maximum speed phase.[22] Studies indicated that force production during jump task at 100ms (F100ms) could be a great indicator for sprint performance.[1,2] Still, few studies have reported data between different time phases of force associated with different phases of 100m performance. As the influential factors mentioned above, each may be interesting to reveal new findings between jumps and sprint performance.

In concern from a complete perspective, the factors including the form, bilateral/unilateral or force at specific time phases of jumps should all be taken into consideration to access sprint performance. Moreover, this relationship may be different in each phase in 100m. To date, various types of sprint performance research have examined the relationship among different phases of sprint performance with different forms of jump such as unilateral/bilateral and force at specific time phase measures, but no clear consensus has been made from experimental data on the fact that few have included the all factors in the same study. There is a need for further investigation of jump performance and time specific force values from those jumps with sprint performance. In our view, both SJ and DJ with distinctive forms, may provide clearer understanding in acceleration and high speed running in unilateral jumps and forces at specific time phases in given time. The primary aim of the current study was to assess the relationships between the jumps and sprint performance in teenage sprinters. The hypotheses of the study are 1) 100m initial acceleration performance (5m and 10m) should be more correlated to SJ in unilateral jumps, with force at specific time value. 2) 100m maximum speed phase (50m-60m) should be more correlated to DJ in unilateral jumps with force at specific time value.

EQUIPMENT AND METHODS

Subjects

A total of 15 male teenage sprinters (age: 14±2 years, height: 168±2 m, mass: 61±1 kg, 100m sprint time:12.42±0.18sec) who had at a minimum of two years participation in sprint, resistance and plyometric training (including jumps tested in this experiment) and are currently competitive in sprint event were recruited in the study. Subjects were fully informed about the experimental purpose, protocol involved before informed consents were signed to participate in this study.

Measure

The study was executed during off-season after subjects were fully rested for two days. A cross-sectional experiment design was undertaken over two days of testing. Subjects were familiar with the types of testing in the experiment for the specific jump and sprint in their daily training. To eliminate the influence of fatigue, potential supplement, daily hobbie, subjects were instructed on required behavior preceding the experiment, including avoiding intensive exercise, a minimum of 8 hours of sleep, keeping clear from performance enhancing supplements such as food containing caffeine prior to data collection.

Design and Procedures

Jump testing

All Jump tests were followed by subjects' own individual static/dynamic warm-up. The following bilateral/unilateral jumps were completed in a randomized order: a) SJ, b) unilateral SJ (USJ), c) DJ, d) unilateral DJ (UDJ). Subjects performed each jump at their maximal effort with the first jump serving as a familiarization trial and the two subsequent jumps retained for data analysis. One minute rest was given between each jump. Unilateral jump tests for right and left legs were followed after all bilateral test. In the tests, subjects' hands were held on their hips to minimize the influence of arm swing and were instructed to jump as high as possible in all jumps under following each jumps' technique crtirias. Squat jump was performed after descending to a 4 seconds stationary position with 90 degrees knee angle, which was achieved by reaching a special made bar that could be elevate to the exact sitting height with 90 degrees knee angle with bottoms. For the DJs, the subjects stepped off of a 40 cm box (20 cm for unilateral test) and dropped to the floor without any extra stepping and jumping movement, being instructed to minimize contact time upon landing for rapid jumping at the maximal effort. The the choice of drop jump height was based on Force platform (Bioware, Kistler, Switzerland) sampling at 1000 Hz was utilized by measuring airtime to calculate jump height. Subject would restart the certain test with 1 minute rest upon the observation of incorrect movement that may affect the outcome of force curve including landing outside the force plate, imbalance posture. Jumping height was determined by the flight time measured from the force plate according to Young et al.[1] The onset thresholds for determining touchdown(s) and take-offs of the jumps t were 5 times the standard deviation of flight force.[23, 24]

$$\text{Jump height (cm)} = gt^2/8$$

Where g is acceleration by gravity (9.81 m s^{-2}), t is the flight time of the jumps.

Data for maximum force, force output at 120ms (the force developed in given time from initial concentric phase of vertical jumps) were obtained from force plate.

Sprint testing

The sprint testing was administered at second day at same location on the Mondo track that is accredited by World Athletic Association. Followed by self-selected warm-up, subjects, in tight-fitting clothing and spikes, ran 60m to assess maximum sprinting performance. The uses of 50m and 60m were by the maximal velocity pretest. Five pairs of Brower split timer (TCI system, Utah, USA) were positioned at 0m, 5m, 10m, 50m and 60m to record subjects' split time of each distance. Fastest time of the trial was retained for data analysis. Subjects started with starting block upon the gun signal fired by a starter official certificated by Chinese Taipei Athletics Association. And they were instructed to accelerate as fast as possible to maintain maximal effort until passing through the final split timer. Two attempts separated with a 10-minute rest interval between the trials were performed to insure subjects were fully recovered. The best time of 2 trials was used for analysis.

Statistical Analysis

Data statistical analyses were carried out on SPSS 22.0 for WINDOWS. Descriptive statistics for all variables were presented as mean and standard deviation (SD). Relationships between sprint parameters and jump parameters were determined using Pearson correlation coefficients (*r*) with the alpha level set at 0.05. Those variables for inclusion were vertical jump height (cm), maximum force (N), force output in 120ms (N@120ms) in all jumps and sprint time (s) measures (5m, 10m, 50m and 60m times). The rationale for using force at time was according to Young et al. The present subjects were teenagers, which require more time to exert force, so the 120ms was used.

RESULTS

The subjects completed the familiarization and testing process without injuries or incidents. The group means for all sprint and jump variables are presented in Table 1. The Pearson result of correlations between sprint times and the jumps variables were displayed in Tables 2 and 3. SJH showed stronger correlation (r=0.826) with 50m sprint performance than SJH (r=0.862). SJ120ms was correlated to 5m sprint performance (r=0.808). USJ120ms was correlated to 10m sprint performance (r=0.834). UDJ120ms showed stronger correlation with 50m sprint performance(r=0.762) than DJ120ms(r=0.825). Among other correlation using maximum force and height, although significant correlations were observed, there were inconsistent results between bilateral and unilateral jumps.

DISCUSSION

In determining sprinting performance, the capability of the lower--extremity musculature to produce large force and impulse during short ground contacts is crucial.[13,16] For the relationships between high speed running and bilateral jump, it was indicated the characteristic of SSC in DJ

Table 1. Mean and standard deviations (SD).

	Mean	SD
5m (sec)	1.43	0.1
10m (sec)	2.19	0.13
50m (sec)	6.76	0.32
60m (sec)	7.93	0.27
DJH (cm)	37.6	10.5
DJmax (N)	1.888.10	616.25
DJ120ms (N)	1599.99	561.72
SJH (cm)	39.4	6.3
SJmax (N)	856.12	154.67
SJ120ms (N)	652.57	135.38
UDJH (cm)	17.3	14.8
UDJmax (N)	797.00	307.84
UDJ120ms (N)	958.74	324.00
USJH (cm)	18.4	3.3
USJmax (N)	523.89	119.00
USJ120ms (N)	138.91	70.30

Note: max is the maximum force of the jump, 120ms is the force output in 120ms.

Table 2. Correlations between SJ, USJ variables and sprint performance.

	SJH	SJmáx	SJ120 m	USJH	USJmáx	USJ120 m
5m	-0.826*	-0.636	-0.808*	-0.862*	-0.891**	-0.654
10m	-0.737	-0.644	-0.271	-0.808*	-0.416	-0.834*
50m	-0.589	-0.896**	-0.426	-0.567	-0.598	-0.356
60m	-0.661	-0.807*	-0.499	-0.535	-0.609	-0.334

Note: * indicates a significance at P<0.05.

Table 3. Correlations between DJ, UDJ variables and sprint performance.

	DJH	DJmáx	DJ120 m	UDJH	UDJmáx	UDJ120 m
5 m	-0,842*	-0,435	-0,296	-0,391	-0,425	-0,505
10 m	-0,803*	-0,253	-0,202	0,072	-0,665	-0,724
50 m	-0,747	-0,771*	-0,762*	-0,326	-0,712	-0,825*
60 m	-0,856*	-0,686	-0,659	-0,403	-0,612	-0,75

Note: * indicates a significance at P<0.05.

that elicits high power during eccentric phase with a relatively smaller knee angle resembles Vmax sprint mechanical movement pattern.[17] Drop jump height was reported by researchers to have positive relationship with Vmax in sprinters (r= 0.59 to 0.7).[5,14] In the present study, DJH and DJmax was highly correlated to 60m and 50m, respectively (r=-.856, r=0.771). On the other hand, SJmax was correlated to 60m but stronger to 50m, and DJ120ms were correlated to 50m. In previous study, Nagahara et al. and Washif et al. found SJH is related to 60m sprint time (r=-0.55; r=0.65).[10,19] Other studies have reported moderate relationships between Vmax and SJ (r = 0.56 to 0.64).[5,14-17] These data are in partial agreement with our study. The difference may be explained by interstudy differences of subject characteristics, it should be noted that teenage sprinters may reach their maximum velocity sooner and have longer ground contact time in high speed running than high level sprinters.[8,25] Therefore, it's reasonable that DJmax and DJ120ms were highly correlated with 50m in our research. For relationship between the unilateral jumps, UDJ120ms, comparing to DJ120ms, showed higher correlations with sprint performance, whereas no relationships were found in USJ for maximal speed (50m and 60m). Abovementioned statements fit our hypothesis in present experiment that unilateral jump at given time may be a predictor in high speed running. To our knowledge, no study has conducted in correlation between unilateral jump and high speed running. Although the correlation for UDJ120ms is not the highest, it's the only factor that shows consistency between bilateral and unilateral jumps. It should be noticed height and maximum force factor in SJ and DJ showed no relations with high speed running comparing to bilateral jump. In spite of the significant relationships between the bilateral jumps and high speed performance indicated by previous studies, there are major differences between maximum force and height given time when comparing the two. This indicated the mere use of maximum force or height to predict sprinting may be inconsistent and certainly should be questioned. Future research here is certainly warranted.

For the acceleration phase, SJH and SJ120ms were significantly correlated to 5m. This could be explained by the nature of the specific hip and knee extensor motion of sprint that a block start begins from stationary posture as the initial steps were concentric based.[6] Squat jump only comprise dynamic and explosive strength with concentric phase, it could be more related to initial acceleration like the 5m portion. Present findings are in accordance with those reported between sprint acceleration performance and SJ ability with the range of correlations (r = 0.22 – 0.86).[1,10-14] Significant relationship was also found between SJ and 7-18m sprint in male sprinters.[19] In DJ, DJH was significantly correlated to 5m. Katja and Coh[14] stated DJH was correlated with in Vmax 20-m sprint running. Consequently, the results of current study are in line with a previous study for the relationship between acceleration phase and bilateral jump ability.

For relationship between the unilateral jumps and acceleration performance, it showed very different results from the bilateral jumps. In USJ, it's interesting that the significant correlation in USJ120ms with 5m shift to 10m with stronger correlations. This appeared to make more sense because after the start athletes shift to unilateral and concentric movement, which 10m performance is largely depended on. This may explain the relationship between USJ120ms and 10m performance. Besides, it again shows very different results from bilateral jumps when only use maximum force and height. The USJmax showed stronger correlation with 5m, but it wasn't the case in SJmax. DJH was correlated to 5m, but wasn't in UDJH. Conceivably, this further indicated our hypothesis that using unilateral jump with forces specific time is better in predicting sprint performance.

CONCLUSION

The results of our study supported the perspective that sprinting and jumping abilities are highly related. Our results highlighted the jumps that have similar form with certain force outputs at specific event timing could be more precise to predict sprint performance in teenage sprinters. USJ120ms and UDJ120ms could better predict acceleration (10m) and high speed phase (50m) in sprint performance respectively. Even though the authors acknowledge that correlations of the using height and forces in jumps from the current study may correspond with previous study, we strongly recommend coaches and practitioners should take cautions when taking jump maximum force and height to predict specific sprint performance since the results could be inaccurate when specific movement variables are not thoughtful considered. This paper illustrates the need for further research within relationships between sprint performance and the forces at movement-specific time phase. Moreover, due to the subjects' age limitation and randomized jumping test order, it should be note the young athlete who have unilateral test first may have muscle fatigue issue. And the time phase that should be used may be different among different subjects due to the support time difference in different 100m phase. Future research should consider to regulate beforementioned factors to address what the current study could not.

ACKNOWLEDGEMENTS

We thank the Dr. Juihung Tu, the director of National Pingtung University Sports Biomechanics lab, and his team, especially Poyi Tai, for the help with experimental data collection and the equipment support for this research.

All authors declare no potential conflict of interest related to this article

AUTHORS' CONTRIBUTIONS: Each author made significant individual contributions to this manuscript. TSL: collected new evidence composed the manuscript. BZ and SCC: theoretical support and data acquisition and processed. WC and ZBZ: structure of paper and test plan.

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