Original Article

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The relationship between countermovement jump performance and sprinting speed in elite sprinters

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Abstract: Data regarding associations between vertical jumping and sprinting ability is lacking in elite sprinters. Therefore, the aim of this study was to evaluate relationship between variables such as countermovement jump (CMJ) height, relative peak power, and sprint time including flight time and ground contact time across various distances in the 50-m sprint among elite sprinters. Twenty-three male sprinters performed two CMJ attempts followed by two 50-m sprints on an indoor track. Jumping performance was assessed via force plates, while sprint times were recorded using timing photocells, with gates at 0, 5, 20, 30, and 50-m. Results showed a statistically significant negative correlations ranging from large to very large, between CMJ height and sprint time ($p<0.01$; r= -0.56 to -0.73) across specific distances. Similarly, a significant large to very large correlations was found between CMJ relative peak power and sprint time ($p<0.01$; r= -0.61 to -0.85) at the studied distances. Furthermore, a large significant correlations was indicated between sprint contact time and sprint time at certain distances ($p<0.01$; r= -0.55 to 0.62), while sprint flight time correlated with distances above 20-m sprint time ($p<0.05$; r= 0.45 to 0.48) and with the 20-50-m flying start sprint time ($p<0.05$; r= 0.48), reaching a moderate magnitude. These findings suggest a significant negative correlation between relative peak power, CMJ height and sprint times across various distances, highlighting the potential for individualized training based on distinct sprint phases. Remarkably, the strength of these correlations increase with longer sprint distance.

Keywords: correlations, power, sprint kinematics, spatiotemporal parameters

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INTRODUCTION

Sprinting ability is a critical component of athletic performance in both team [1] and individual sports [2,3]. Based on the distance covered, sprinting skills can be broken down into two groups: acceleration (0–30 m) and maximum speed (30–100 m) [4]. These skills are influenced by various factors, such as power, sprint-specific endurance, and technique, with their magnitudes varying depending on the distance [5].

The relationship between sprinting speed, strength, and power variables has been a topic of ongoing scientific and practical debate for several years [5–8], yet there is a notable gap in research focusing specifically on elite track and field sprinters. Studies indicate that the initial ground contact phases are dominated by propulsive forces rather than breaking forces [4]. Here significant correlations have been registered between the average propulsive forces and initial running velocity. Studies emphasize the dominance of concentric contractions in the initial steps of the sprint, and the significant correlations of a propulsive force of the sprint in maximizing initial running velocity [9,10]. On the other hand, during top-end speed sprinting lower limb muscles contract eccentrically with a very short support phase and a significant contribution of elastic energy through the stretch-shortening cycle [11]. Therefore, as the sprint speed increases, the demand for power also increases.

The measurement and development of lower limb power specific to the movement pattern of sprinting is difficult and requires sophisticated technology. For example, the SPRINT 1080 engine-assisted measuring system (1080 Motion AB, Stockholm, Sweden) can be used for the precise selection of load in resisted or assisted sprints training, thus focusing the training on a particular sprinting distance development [12]. Alternatively, jumping drills are widely used by researchers and practitioners as an indirect test and method to develop lower limb power [13]. Although sprinting and jumping require the production of force with a different vector, research indicates significant correlations between these tasks [14–16].

Shalfawi et al. [16], reported strong negative correlation between 40-m sprint time and CMJ relative peak power in professional basketball players. Moreover, Kale et al. [14] found a significant correlation between maximum velocity obtained during 100-m and CMJ height in subelite sprinters (mean for 100m sprint time: 11.62 ± 0.41s). Study by Loturco et al. [15] confirms such finding showing that jumping height (in CMJ and squat jump) are strongly correlated to sprinting speed in elite sprinters (including Olympic medalists). Similarly, Washif and Kok [17] indicated increasing with sprint distance (from 10-m to 60-m, with moderate to very large correlations; respectively) negative correlations between squat jump height and relative peak power in young male elite sprinters (mean for 100m sprint time: 10.50 ± 0.18s). Nevertheless, there is still little of such data on elite sprinters compared to team sports [14], and considering relationships in vertical jumping performance and stride kinematics, such as flight and ground contact time. According to the authors' best knowledge, only in the study by Kale et al. [14], besides the associations between vertical jumping and sprint time, correlations with ground contact time and flight time during sprint were also investigated. The study did not find significant correlations between ground contact time, flight time, and sprint time, as well as between CMJ and squat jump and drop jump. However, the authors did not conduct separate analyses with particular sprint phases, so these results refer only to the full distance, and it is unknown whether any relationships would be found at other distances.

Considering the aforementioned factors and aiming to increase knowledge regarding associations between vertical jumping and sprinting ability for assessing and monitoring qualities related to sprinting performance, as well as for prescribing training in sprinters, this study aimed to evaluate the relationships between variables such as CMJ height, relative peak power, and sprint time (including flight time and ground contact time) across various distances in the 50m sprint among elite sprinters. We hypothesized that both CMJ height and relative peak power would exhibit significant correlations with sprint time and ground contact time, indicating that higher jump height and relative peak power would correspond to shorter sprint times and ground contact times, thus reflecting better sprint performance.

MATERIAL AND METHODS

Participant

Twenty-three male sprinters of the Polish National Team (from 100 to 400m) participated in this study (age: 20.8 ± 4.4 years; body mass: 73.7 ±6.5; body height: 182 ± 5; 100m best time: 10.66 ± 0.41s). The group of athletes included participants of the European and World Track and Field Championships (they constitute 14 out of 23, while 6 of them were medalists). The study was conducted at the training camp beginning of the indoor season. To minimize fatigue, athletes refrained from exercising for 48 hours before testing, maintained regular sleep and dietary routines, and abstained from consuming caffeine-containing beverages or supplements, as well as other drugs that might indirectly affect the athletes' speed.

Ethics

Athletes received comprehensive information about the study, including potential risks, before providing written informed consent. They were assured of the option to withdraw at any point, and the study's anticipated outcomes were intentionally undisclosed. The protocol was approved by the Bioethics Committee for Scientific Research (3/2021) at the Jerzy Kukuczka Academy of Physical Education and performed according to the ethical standards of the Declaration of Helsinki 2013.

Experimental Session

Testing was performed on an indoor certificated synthetic track. All athletes used their sprint spikes during sprinting and regular running shoes during jumping assessments. All of the athletes performed a sprint-specific warm-up that was consistent with participants' normal training habits and then proceeded to perform CMJ and 50m sprint attempts.

Countermovement Jump Performance Assessment

The countermovement jump with arm swing was performed on a force plate (ForceDecks, Vald Performance, Australia) with a sampling rate of 1000 Hz, which has been previously confirmed as valid and reliable [18]. Each athlete performed two attempts of CMJ with an arm swing. Athletes dropped into the countermovement position to a self-selected depth and immediately followed by a maximal effort vertical jump. The athletes were instructed to land in the same position as the take-off in the midsection of the force plate. The participant returned to the starting position after each jump, and the procedure was completed for a total of 2 jumps with a 30 second rest interval between jumps. The CMJ test was familiar to all athletes as they had performed it previously as part of regular fitness assessments. The jump height from take-off velocity and relative peak power were evaluated. The best jump in terms of height was kept for further analysis.

Sprint Performance Assessment

Sprint times were recorded using timing photocells (Microgate, Bolzano, Italy), with gates at 0, 5, 20, 30, and 50 m. To prevent premature triggering by swinging limbs, the gates were set at approximately 1 meter above the ground, corresponding to the athletes' hip height. Athletes initiated their sprints from a crouched position, positioned 0.3 meters behind the initial timing gate, ensuring a controlled start. The OptoJump–Microgate optical measurement system (Microgate, Bolzano, Italy) was employed to capture kinematic variables, specifically ground contact time and flight time, during the sprint steps. This system utilized interconnected rods equipped with optical sensors, distributed along the track's length and width. The two attempts were performed, which were measured with precision to the nearest 0.001 seconds, and the fastest 50m sprint time was selected for further analysis.

Statistical Analysis

All statistical analyses were performed using SPSS (version 25.0; SPSS, Inc., Chicago, IL, USA) and were shown as means with standard deviations (±SD) with their 95% confidence intervals (CI). Statistical significance was set at $p<0.05$. The relative reliability, (two-way mixed effects, absolute agreement, single rater intraclass correlation coefficient), and the absolute reliability (coefficient of variation), were computed using the both attempts data. The Shapiro–Wilk was used to verify the normality of the sample's data distribution. Pearson's product-moment correlation coefficient (r) or Spearman's rank correlation (rs) was used to analyze the relationship between particular sprint distances, contact and flight time vs. CMJ height and relative peak power. Furthermore, a stepwise regression analyses were performed with CMJ jump height, relative peak power, sprint ground contact time and flight time set as independent variables (predictors) and sprint time at particular distances as the dependent variable. The common variance between variables was described with the coefficient of determination (R2). Thresholds for qualitative descriptors of correlations were interpreted as: trivial (0.0–0.09), small (0.10–0.29), moderate (0.30–0.49), large (0.50–0.69), very large (0.70–0.89), nearly perfect (0.90–0.99), and perfect (1.0) [19].

RESULTS

Shapiro-Wilk test indicated that data distribution was violated only in the case of flying 20-50m sprint time ($p=0.01$). Descriptive data for all studied variables along with reliability are shown in Table 1, while correlations between all measured vairables are presented in Table 2.

Table 1. Descriptive data and intersession reliability.

Variable	Mean ± SD (95%CI) (Mdn)	Mdn; IQR	ICC (95%CI)	CV (%)
Contact Time [ms]	112 ± 10 (107 to 116)	110; 15	0.988 (0.927 – 0.995)	1.3 ± 0.6
Flight Time [ms]	108 ± 7 (105 to 112)	108; 13	0.956 (0.898 – 0.981)	1.7 ± 1.1
5m [s]	0.716 ± 0.081 (0.681 to 0.752)	0.716; 0.095	0.916 (0.802 – 0.964)	3.4 ± 2.7
20m [s]	2.515 ± 0.122 (2.462 to 2.568)	2.511; 0.15	0.950 (0.853 – 0.980)	1.6 ± 3.1
30m [s]	3.565 ± 0.165 (3.493 to 3.636)	3.544; 0.197	0.979 (0.938 – 0.992)	0.7 ± 0.8
50m [s]	5.561 ± 0.257 (5.449 to 5.672)	5.510; 0.34	0.990 (0.966 – 0.997)	0.4 ± 0.6
Flying 20-50m Time [s]	3.046 ± 0.146 (2.983 to 3.109)	3.036; 0.209	0.981 (0.956 – 0.992)	0.7 ± 0.8
Jump Height [cm]	60.0 ± 8.8 (56.2 to 63.8)	62.5; 13.9	0.952 (0.887 – 0.980)	3.2 ± 3.1
Relative Peak Power [W/kg]	78.5 ± 11.7 (73.4 to 83.5)	76.5; 11.1	0.994 (0.869 – 0.976)	3.5 ± 3.3

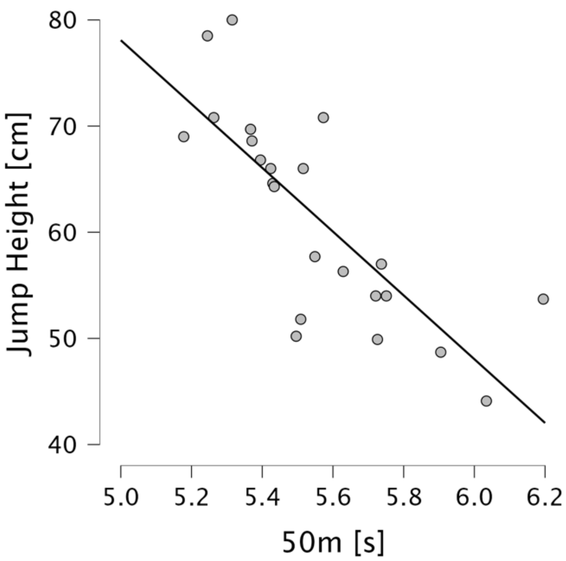
SD – standard deviation; CI – confidence interval; Mdn – median; IQR - interquartile range; ICC – intraclass coefficient correlation;; CV – coefficient of variation

Table 2. Correlations between studied variables

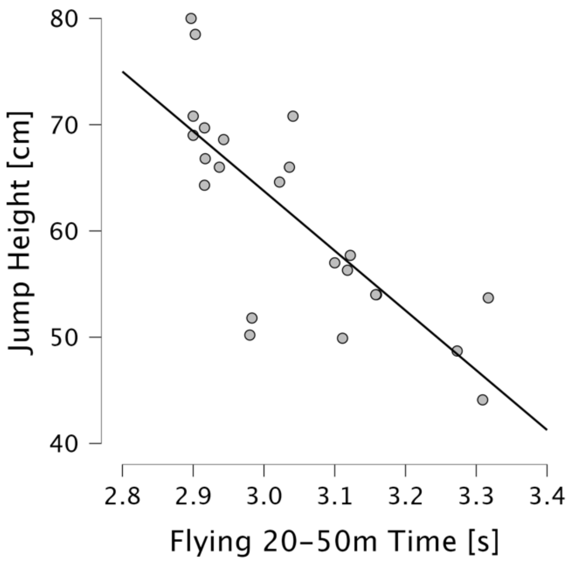
Variable	Jump Height	Relative Peak Power	Contact Time	Flight Time
Contact Time [ms]	-0.564**	-0.433*	-	0.15
Flight Time [ms]	-0.693**	-0.614**	0.15	-
5m [s]	-0.700**	-0.627**	0.582**	0.396
20m [s]	-0.711**	-0.645**	0.621**	0.449*
30m [s]	-0.729**	-0.849**	0.565**	0.483*
50-m Time	-0.711**	-0.645**	0.621**	0.449*
Flying 20-50 m Time	-0.729††	-0.849††	0.565††	0.483†

* statistically significant Pearson's correlation at p<0.05; ** statistically significant Pearson's correlation at p<0.01; † statistically significant Spearman's rank correlation at p<0.05; †† statistically significant Spearman's rank correlation at p<0.01;

Results indicated statistically significant negative correlations, ranging from large to very large magnitude, between CMJ height and sprint time (p<0.01; r= -0.56 to -0.71 and rs=0.73 in case of flying 20-50 m time; Figure 1) across particular distances, suggesting that a higher jump height corresponds to better sprint performance. Similarly, a significant large to very large correlation was found between CMJ relative peak power and sprint time (p<0.01; r= -0.61 to -0.85 and rs= 0.85 in case of flying 20-50 m time) at the studied distances (Figure 2). Furthermore, a large significant correlation was indicated between sprint ground contact time and sprint time at specific distances (p<0.01; r= -0.55 to 0.62 and rs= 0.57 in case of flying 20-50 m time), while correlations with sprint flight time were found with the distances above 20-m sprint time (p<0.05; r= 0.45 to 0.48) and time obtained in the 20-50-m flying start sprint (p<0.05; rs= 0.48), reaching a moderate magnitude. No significant correlation was found between sprint ground contact time and flight time.



(A)



(B)

Figure 1. Correlations between 50 m (A) and flying 20-50m sprint time (B) with countermovement jump height.

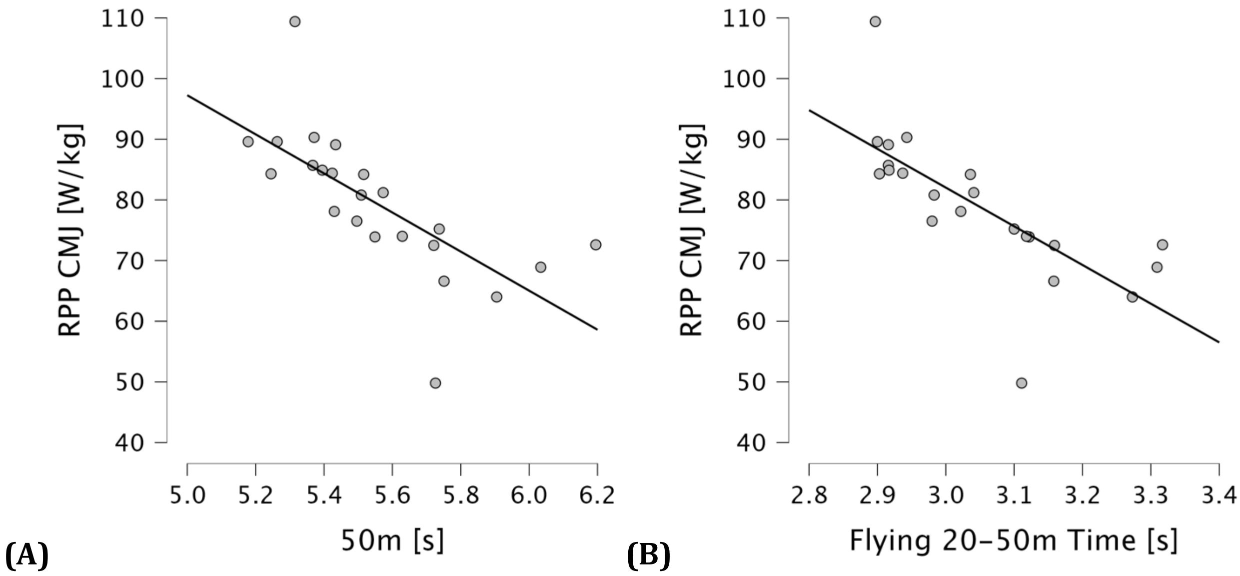


Figure 2. Correlations between 50 m (A) and flying 20-50m sprint time (B) with countermovement jump relative peak power.

The regression analyses revealed that only one prediction model was significant, specifically for the flying 20-50m sprint time. The prediction model of CMJ height, ground contact time and flight time were able to explain up to 75% of the flying 20-50m sprint time. The regression model for the flying 20-50m sprint time took the form:

$$Flying\ 20 - 50m\ sprint\ time = 2.486 - 0.007 \times CMJ_{height} + 4.425 \times GCT + 4.641 \times FT$$

In terms of practical implications, it means that if the CMJ height increases by a centimeter, the flying 20-50m sprint time decreases by 0.007 s. On the other hand, if the ground contact time or flight time increases by 0.10ms, the flying 20-50m sprint time increase accordingly by 0.442 s or 0.464 s.

DISCUSSION

The aim of this study was to determine the relationship between the CMJ height, relative peak power and various time parameters (time, ground contact and flight times) during a 50m sprint in elite sprinters. The main finding of this study was that both the CMJ height and relative peak power are significantly negatively correlated with the sprint time recorded at various distances. Notably, the strength of these correlations increases with the sprint distance. On the other hand, as the sprint distance extends, positive correlations were observed between sprint time and both contact and flight times. Furthermore, the strongest negative correlations were found between CMJ height and relative peak power and flying 20-50m sprint time, both very large. Additionally, the results showed that a large amount of the sprint time (up to 75% using an adjusted coefficient of determination) could be explained by a model including CMJ height, ground contact time, and flight time during sprint.

In line with previous research [15-17], our study indicated a significant negative correlation between CMJ height, relative peak power and sprint time in elite sprinters, suggesting that higher jump height and power are associated with better sprint performance. In the study by Kale et al. [14], a significant negative correlation was found between CMJ height and 100m sprint time in male sprinters. Washif and Kok [17] reported significant negative correlations between CMJ height, relative peak power, and the 30m and 60m sprint times, as well as with flying distances of 10-30m and 30-60m. Loturco et al. [15] also demonstrated significant negative correlations between CMJ height and sprinting at 10m, 30m, and 50 m. Despite the differences in force vectors between vertical jumps and sprints, the similarity in muscles involved and muscle action velocity appears to account for the reported relationships. Ballistic exercises, like jumping, eliminate the deceleration phase and requires the athlete to continuously generate force throughout the entire range of motion, replicating lower limb "triple extensions" seen in sprinting. Moreover, available data show comparable contribution of ankle, knee and hip joints to accelerate the body mass during vertical jumping and sprinting [20,21]. Therefore, it is possible that improvements in CMJ height in this particular group of athletes can result in improved sprint performances.

In current study, large and medium negative correlations were observed between CMJ height and relative peak power with 5m sprint. However, these correlations significantly increased with the 50m sprint, reaching very large and large magnitudes. The relationships were even higher during flying distance of 20-50m, with both the CMJ height and relative peak power showing very high values. Similar phenomena were observed in the study by Washif and Kok [17], where authors found no significant correlations between CMJ height and relative peak power with the 10m sprint time (r= -0.28 and -0.44, respectively). However, the correlations became significant at 30m (r= -0.54 and -0.60) and 60m sprints (r= -0.55 and -0.67). Furthermore, greater correlations were revealed between flying distances of 10-30m (r= -0.76 and -0.74) and 30-60m (r= -0.62 and -0.73). Sprinters typically reach their highest speed between 50m and 80m [22], with advanced sprinters accelerating over longer distances. Therefore, it seems that the relationships between CMJ height and relative peak power are particularly strong during the acceleration phase and gradually intensify as speed increases. These findings are also somewhat supported by the results of the study by Kale et al. [14], where correlations between CMJ height and 100m sprint time had lower magnitudes than in this study and those mentioned earlier. This underscores the importance that, if the goal is maximal acceleration development in sprinting, training methods to increase CMJ height and relative peak power are required.

Additionally, in this study we also noted positive high correlations between contact time and sprint time, progressively increasing with the extended sprint distance. The model comprising CMJ height, ground contact time, and flight time suggests that sprinters with higher CMJ height, shorter ground contact time, and flight time typically achieve better flying sprint performance. This confirms that individual sprint phases may require slightly different training approaches. Findings of the current study provides valuable practical implications for developing sprint capabilities as the longer distances appear more reliant on stretch-shortening cycle performance and contact time. Therefore, as an example, if an athlete specifically needs to enhance top-speed capabilities, they may engage in vertically-oriented jumps to develop fast stretch-shortening cycle ability (e.g., drop jumps with an emphasis on minimizing contact time). As demonstrated by our provided model, striving to improve CMJ height and reduce ground contact and flight time during the sprint can contribute to nearly 75% reduction in sprint time over the flying 20-50m sprint phase. Conversely, exercises involving longer contact times might be employed to enhance the early acceleration phase of the sprint (i.e. first 10m). However, this training approach require the implementation of long-term intervention studies.

Results of this study have to be considered with the following limitations. The participants in this study were elite sprinters, so extrapolating these findings to other populations should be done with caution. Additionally, our study was limited to CMJ height and relative peak power, making it inappropriate to assume that similar associations would manifest with these variables in other vertical jumps. It is also important to note that only the contact and flight times among the spatiotemporal variables of sprinting were investigated. This limitation may also extend to the fact that we solely analyzed sprints over a 50m distance and its individual sections, without evaluating the performance of the entire 100m sprint.

Overall, these findings suggest that the relationships between CMJ height, relative peak power, and sprint time strengthen as the sprint distance increases, highlighting the importance of considering slightly different training methods to improve particular sprint distances. From a practical standpoint, evaluating CMJ performance could be a simple, low-injury risk, time-saving and low-demanding method to frequently assess sprinters' performance and training level. Additionally, if the goal is to increase the relative acceleration ability of a sprinter, training methods that enhance CMJ height and reduce ground contact time and flight time during sprinting should be prioritized. Collectively, these factors may lead to faster overall 100-m sprint times. Future research should focus on evaluating long-term effects of jumping training on sprint performance and should assess the relationships between the 100m sprint and its individual sections with various variables in both the concentric and eccentric phases of vertical jumps to provide further insight into sprinting.

CONCLUSION

The findings of this study indicate i) a significant negative correlation between relative peak power and CMJ height with sprint times across various distances; ii) the strength of these correlations increases as the sprint distance lengthens, with similar patterns observed between sprint time and both sprint ground contact and flight times; and iii) most notable relationships were identified between CMJ height, relative peak power, and flying 20-50m sprint time, demonstrating very large associations.

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