IS THERE ANY TRANSFER BETWEEN COUNTERMOVEMENT JUMP AND SWIMMING TRACK START PERFORMANCE?

Diogo D. Carvalho [1,2], Pedro Fonseca [2], Daniel A. Marinho [3,4], António J. Silva [4,5], Rodrigo Zacca [1,2], Luís Mourão [1,2], Ricardo J. Fernandes [1,2] and J. Paulo Vilas-Boas[1,2]

Centre of Research, Education, Innovation and Intervention in Sport, Faculty of Sport, University of Porto, Porto, Portugal[1]
Porto Biomechanics Laboratory, University of Porto, Porto, Portugal[2]
Department of Sport Sciences, University of Beira Interior, Covilhã, Portugal[3]
Centre of Research in Sport, Health and Human Development, Portugal[4]
Department of Sport Sciences, University of Trás-os-Montes and Alto Douro, Vila Real, Portugal[5]

The aim of this study was to determine if the countermovement jump could predict swimming starts performance. Ten elite swimmers performed one maximal countermovement jump on an extensometric force platform and three maximal track start on an instrumented starting block. Results showed an inverse relationship between 15 m starting time and jump variables (r = -0.86, -0.64 and -0.92 for jump height, peak vertical force and peak power, respectively; $p < 0.05$) and no significant correlation between relative peak vertical force and start variables. Regression equation for 15 m time prediction was defined by jump height and peak vertical force ($r = 0.890$, adjusted $r^2 = 0.734$). In addition, results suggest that swimmers with higher jumps and higher peak vertical force are faster on the 15m mark when using a track start.

KEY WORDS: kinematics, kinetics, force, power, swimmers, performance prediction.

INTRODUCTION: Competitive swimming events are commonly divided in starting, stroking and turning phases, with start time representing ~25% of the total race time depending on the event. Thus, the first section of a swimming race is determinant for the final outcome, with ventral starts enabling faster water entries than the average swimming speed, positively influencing the race outcome. In general, jumping performance potential is measured by jump height or, more specifically, by the maximum rise of body's center of mass after take-off, particularly during the countermovement jump (CMJ). This is frequently used on dry land training as a test to evaluate lower limbs explosive power and in swimming can simulate starts and turns (jump and contact with the wall and push off, respectively).
Previous studies found: (i) direct relationships between total work and jump height and lower limbs power in tethered swimming (Morouço et al., 2011) and between CMJ performance and flight distance following grab, swing and rear-weighted track starts (Breed & Young, 2003); (ii) inverse relationship between lower body strength and 15 m time (West, Owen, Cunningham, Cook, & Kilduff, 2011); and (iii) an absence of relationships between jump vertical force and swimming starts horizontal force (De la Fuente, Garcia, & Arellano, 2003). The aim of this study was to determine if the CMJ could predict swimming starts overall performance, being hypothesized that CMJ related variables would be well correlated with swimming starts performance, particularly with the 15 m mark.

METHODS: Ten swimmers from the Olympic and Pre-Olympic Portuguese swimming team, five male and five female (age: 21.6 ± 3.9 vs 18.8 ± 2.4 years, body mass: 79.8 ± 9.7 vs 63.5 ± 1.3 kg, height: 182.8 ± 3.0 vs 170.1 ± 4.4 cm, IMC: 23.8 ± 2.5 vs 22.0 ± 1.3 and best competitive performance: 842.8 ± 13.3 vs 810.2 ± 33.6 FINA points, respectively) participated in this study. Swimmers and coaches were informed about the purpose of the evaluations and any known risks, providing individual consent for participation. One maximal vertical countermovement jump (CMJ) was performed after proper familiarization, with the jump height (maximum minus the initial values reached by the trochanter's marker) measured by means of a Qualisys motion capture system (Qualisys AB, Gothenburg,

Sweden) operating at 200 Hz. Peak vertical force (maximal absolute force produced during the jump) was assessed through an extensometric force platform (Bertec Inc., Columbus, Ohio, USA) operating at 2000 Hz and, from it, was calculated the relative peak vertical force (variable value divided by the swimmer's weight, in percentage). Maximum jump power was also calculated, as 60.7 × jump height (cm) + 45.3 × body mass (kg) – 2055 (Sayers, Harackiewicz, Harman, Frykman, and Rosenstein, 1999).
In addition, three maximal 15 m front crawl trials (with 5 min minimum rest in-between), using the track start technique on an instrumented starting block (cf. Mourão et al., 2015), were performed for collecting starting time data (the best trial was chosen for subsequent analysis). Variables analysed for the starts were: (i) the duration of each start phase, particularly the reaction time (between the starting signal and the first visible change in the starting block reaction forces), back feet take-off (between starting signal and loss of contact from the back foot with the back-plate - zero load on the rear force platform), front foot stand (stand-by time with front foot only), block time (between starting signal and the block loss contact - referred as "reaction time" by the timing systems), movement time (since the first visible change of the block reaction forces and the loss of contact - block time subtracted to reaction time) and (ii) the 15 m time (time until the head crosses the 15 m mark).
Nonparametric statistical procedures were adopted due to the reduced sample. Spearman correlation coefficients were calculated between CMJ and start related variables using 0 - 0.25 (little), 0.26 - 0.49 (weak), 0.50 - 0.69 (moderate), 0.70 - 0.89 (strong) and 0.90 - 1.0 (very strong) correlations (Blikman, Stevens, Bulstra, van den Akker-Scheek, & Reininga, 2013) for a $p < 0.05$ level. Regression analysis was used to access the relationship between CMJ variables and 15 m time start performance. All statistical procedures were conducted on SPSS 19.0 statistical software (IBM, USA).

RESULTS AND DISCUSSION: For CMJ, the height was 0.47 ± 0.09 m, with a peak power of 4010.7 ± 776.5 W, higher than found in previous studies (West et al., 2011 and Sayers et al., 1999), and the peak absolute and relative vertical forces were 1602.7 ± 313.9 N and 227.2 ± 18.5% body mass. In the starts performance it were observed values of 0.163 ± 0.047 s for reaction time (lower than presented by Barlow, Halaki, Stuelcken, Greene, & Sinclair, 2014, probably due to the different methods used), 0.587 ± 0.063 s for take-off of the back foot, 0.135 ± 0.017 s for front foot stand, 0.721 ± 0.059 s for block time (higher than that found by Wilson and Marino, 1983, probably explained by the fact that the timing system stop counting when actual “zero” load value was reached in the instrumented block when normally current swimming pool timing systems uses a critical value higher than zero), 0.560 ±0.031 s for movement time and 6.382 ± 0.757 s for 15m time. Overall start performance was more than 0.5 s better than the reported by West et al. (2011), evidencing a higher performance level of this study sample.

Table 1 presents the relationships between CMJ and start related variables, with jumping height presenting a strong negative correlation with 15 m time, peak vertical force a strong negative correlation with movement time and moderate negative relationship with 15 m time. Peak power showed a moderate negative correlation with block time, a strong negative correlation with movement time and a very strong negative correlation with 15 m time. Relative peak vertical force was not correlated with start variables.
Results showed that the CMJ vertical force absolute value is more useful to predict start performance than the relative one, possibility because body weight (BW) is decreased when submersed in water (Taylor, Stratton, MacLaren, & Lees, 2003). It is easier for a swimmer that have a weight of 80 kg to generate 1500N of jump vertical force (187.5% BW) than a swimmer with 50 kg (300% BW), evidencing that anthropometry is very important in start performance (cf. Zatsiorsky, Bulgakova, and Chaplinsky, 1979). No relationships were found between jump variables and reaction time, back foot take off and front foot stand. Results for reaction time were surprising since that variable is not expected to improve over time, but back foot take-off from and front foot stand time were probably related because the most

important demonstration of force in vertical jumps is the explosive force. However, p value lower than 0.10 from take-off from back foot demonstrate that further investigation should be done since it could be affected by the lower subjects number.

Table 1
Correlation coefficients (and p values) between countermovement jump (CMJ) and start variables.

Variables	Reaction time (s)	Take-off from back foot (s)	Front foot stand (s)	Block time (s)	Movement time (s)	15 m time (s)
CMJ height (cm)	-.47(.166)	-.58(.080)	.21(.561)	-.52(.126)	-.43(.217)	**-.86(.002)**
Peak vertical force (N)	.27(.455)	-.37(.291)	.17(.645)	-.47(.166)	**-.71(.022)**	**-.65(.043)**
Relative peak vertical force (%BM)	.03(.934)	-.37(.291)	.25(.480)	-.49(.148)	-.31(.390)	-.32(.365)
Peak power (W)	-.16(.650)	-.53(.116)	.01(.973)	**-.67(.036)**	**-.80(.005)**	**-.92(.000)**

The inverse relatioship between movement time and jump vertical force and power seem to indicate that it is important to produce high force values in short time periods. This was also evidenced by the inverse relationship between block time and peak power leading to the suposition that as faster swimmers produce force, less time they spend in the block. We have found inverse relationships between 15 m time and jump height and peak power as presented before (cf. West et al., 2011). Then, a regression model including the CMJ was done and, after analyzing the effect of collinearities in predictable variables and because peak power is an estimated value itself, the best model to predict 15 m time included the CMJ height and peak vertical force (r = 0.890, adjusted r^2 = 0.734). This model significantly explains 15 m time, with the standard error of the estimation of ± 0.39065 s (F = 13.387, p = 0.004), with the following regression equation:

$$\mathbf{15\ m\ time = 10,964\ - (0.064 \times CMJ\ height) - (0.001 \times peak\ vertical\ force)}$$

As represented in the equation, the higher the jump is and the more vertical force before leaving the ground swimmers produce, the better will be the swimming start performance. It was found a mean ± SD difference of 0.27 ± 0.19 s between observed and predict 15 m time, with a difference lower than 0.13 s for three swimmers and lower than 0.05 s for one swimmer. Table 2 presents the comparison between observed and predict 15 m time, with no difference found (p > 0.05), demonstrating this model usefulness to predict overall start performance. In fact, if a swimmer does not reach the predicted performance, it could be attributable to a poor starting technique.

Table 2
Mean ± SD of observed and predicted 15 m time and corresponding comparison.

Variable	Observed value (Mean ± SD)	Predicted value (Mean ± SD)	Wilcoxon test	
			z	ρ
15 m time (s)	6.38 ± 0.76	6.39 ± 0.67	-.153	0.92

The CMJ seems to be a useful tool for coaches predict starts performance improvements and for developing swimmers' skills. It is a simple exercise and, as it uses the same explosive movement type than swimming starts, it could be included in dry land routines. However, it should be highlighted that the current swimmers are very proficient on the track start technique, reason why young and low level swimmers need first to learn the proper start technique skills before increasing the amount of force in dry land exercises. In addition, the low number of participants did not allow comparing genders, which should be a concern of future studies, as well as including different ventral start techniques (e.g. grab start).

CONCLUSION: Data evidenced that CMJ can be used to evaluate and predict track start swimming performance and should be included in all dry land routines.

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