# THE WEDGE EFFECTS ON VERTICAL FORCE-TIME CURVE INSTANTS AND ON BACKSTROKE START PERFORMANCE

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This study compared vertical force and time at time reference points between backstroke start performed with and without wedge, and identified the relationships with 5 m start time. Ten swimmers (age 21.1 ± 5.36 years, stature 1.78 ± 0.04 m, body mass 72.82 ± 10.05 kg and mean 100 m backstroke performance of 59.67 ± 2.89 s) completed eight backstroke starts (four with and four without wedge) using the highest horizontal handgrip. An instrumented starting block recorded vertical force and time at the following points: (i) start signal; (ii) peak before hands-off; (iii) minimum at hands-off; and (iv) peak before take-off. Forces at instants after the start signal were greater when using the wedge and no relationships were observed between force, time at reference points and 5 m time. The wedge use can benefit vertical forces generation but not directly 5 m time.

**KEYWORDS:** external forces, instrumented block, time reference points, start time

**INTRODUCTION:** The backstroke start technique has evolved mainly due to the on-going swimming rules driven by changes in starting block design (de Jesus et al., 2015). In 2013 the Federation Internationale de Natation authorized a wedge for feet support to minimise the foot slipping exposure. Its inclusion can prevent part of the friction mechanism through swimmers' feet indentation and better wall contact, being the vertical reaction force the sum of pure static friction on hallux and a wedge vertical reaction force.
Since the wedge use implementation, some studies have attempted to observe kinematical and kinetic changes (de Jesus et al., 2015; Ikeda, Ichikawa, Nara, Baba, & Shimoyama, 2016; Sinistaj, Burkhardt, & Carradori, 2015), but researchers have focused on forces exerted at the hands. The present study compared the vertical force and time at time reference points when backstroke start was performed with and without wedge, and identified the wedge on the 5-m backstroke start time.

**METHODS:** Ten male national level backstroke swimmers (mean and standard deviations: age 21.1 ± 5.36 years, stature 1.78 ± 0.04 m, body mass 72.82 ± 10.05 kg, training background 12.6 ± 6.13 years and mean performance for the 100 m backstroke in 25 m pool of 59.67 ± 2.89 s) performed randomly eight maximal backstroke start repetitions, with 2 min resting, four with and four without wedge, over a distance of 15 m in a 25 m indoor swimming pool. All start trials were performed over an instrumented starting block composed by two 3D strain gauge waterproof force-plates vertically positioned on a custom built underwater structure fixed on the starting pool wall (de Jesus et al., 2016), each one with its independent wedge attached over the force plate top at 0.04 m fixed positioned above water level according to FINA rules determination (FR 2.10). Data processing software was created in LabView 2013 (SP1, National Instruments Corporation, USA) to acquire, plot and save the

strain readings from each force plate (2000 Hz sampling rate). Ground reaction forces records were analogue-to-digital converted by a module for strain signals reading (NI9237, National Instruments Corporation, USA) and respective chassis (CompactDAQ USB-9172 and Ethernet-9188 National Instruments Corporation, USA).
Swimmers were videotaped with one underwater stationary and synchronised video camera (HDR CX160E, Sony Eletronics Inc., Japan) placed in a waterproof housing (SPK-CXB, Sony Eletronics Inc., Japan) and fixed on a special built support. It operated at 50 Hz sampling frequency with 1/250 s exposure time and was positioned in the lateral (2.6 m away from the starting block wall), perpendicular to the line of swimmer's motion (6.78 m away from the backstroke start trajectory) and 0.20 m below the water surface, allowing the 5 m start time assessment (from start signal until the swimmer's head reaches 5 m mark). Starting signals were produced conform to FINA rules (SW 4.2) using a starter device (Omega Start Time IV Acoustic Start, Swiss Timing Ltd., Switzerland) that simultaneously generated starting command and exported a trigger signal to the force plates.
Two processing custom-designed routines created in MatLab R2014 (The MathWorks Incorporated, USA) were used to: i) convert strain readings (με) into force values (N); ii) filter upper and lower limb force curves ($4^{th}$ order zero-phase digital Butterworth low-pass filter with a 10 Hz cut-off frequency; iii) sum right and left limb force data; and iv) normalize upper and lower limb forces to swimmer's weight (N/N). Each individual vertical force-time curve exerted at feet was normalised in time from the starting signal until the swimmer's feet take-off. Time reference points were characterised in each individual force-time curve and determined force and time as presented in Figure 1.

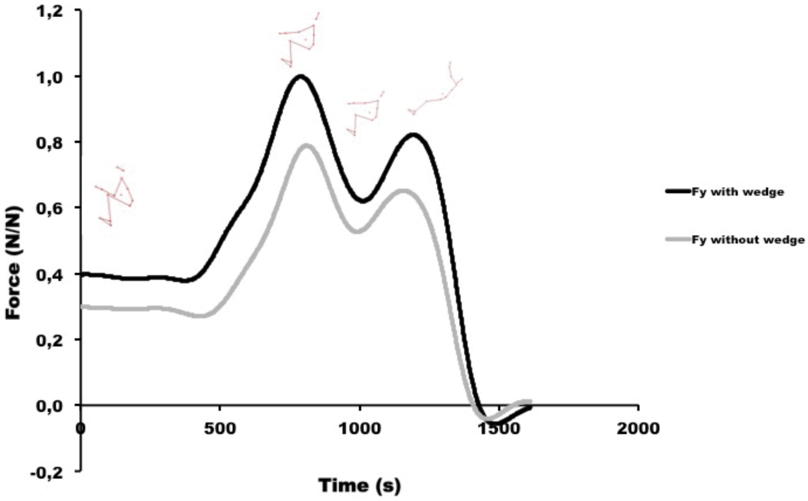


**Figure 1: Individual normalised vertical force-time curves exerted at the feet at backstroke start with hands on the highest horizontal handgrip and feet over/without the wedge (black and grey lines), from the start signal until the swimmer's feet take-off. The time reference points exerted at the feet (start signal, peak force before hands-off, minimum force at hands-off and peak force before take-off are represented with stick figures.**

Changes in kinetic variables between backstroke start performed with and without wedge were analysed through standardised differences and effect size (ES) (Cohen, 1988) with the Hopkins scale was used for their interpretation: 0-0.2 trivial, > 0.2-0.6 small, > 0.6-1.2 moderate, > 1.2-2.0 large, and > 2.0 very large scale used for their interpretation (Hopkins, 2010). Magnitude-based inference and precision was carried out to analyse the chance that the true changes were clear or trivial and probabilities were also calculated to determine whether the true differences were lower than, similar to, or higher than the smallest worthwhile difference or change (SWC, 0.2 x between-subject SD) (Hopkins, Marshall, Batterham, & Hanin, 2009). Spearman correlation coefficient was assigned to determine association between kinetics variables and 5 m time at variation performed with wedge, using the following benchmarks: 0 to 0.25 little, 0.26 to 0.49 weak, 0.50 to 0.69 moderate, 0.70 to 0.89 strong, 0.90 to 1.0 very strong (Blikman, Stevens, Bulstra, van den Akker-Scheek, & Reininga, 2013) with significance accepted at $P < 0.05$.

**RESULTS:** The vertical force and time mean and (SD) at time reference points and 5 m start time are shown in Table 1 for backstroke start performed with and without wedge.

**Table 1: Mean and (SD) of force and time at time reference points and 5 m start time.**

| Variable | With wedge | Without wedge |
|---|---|---|
| Force at start signal (N/N) | 0.40±0.12 | 0.34±0.11 |
| Peak force before hands-off (N/N) | 0.78±0.14 | 0.66±0.06 |
| Time at peak force before hands-off (%) | 49.89±7.27 | 52.96±9.06 |
| Minimum force at hands-off (N/N) | 0.68±0.08 | 0.58±0.06 |
| Time at minimum force at hands-off (%) | 65.49±7.74 | 67.79±6.00 |
| Peak force before take-off (N/N) | 0.76±0.08 | 0.65±0.05 |
| Time at peak force before take-off (%) | 81.33±2.81 | 81.36±3.90 |
| 5 m backstroke start time (s) | 1.96±0.13 | 2.01±0.15 |

Standardised mean difference, 95% confidence interval, magnitude of effect size and probabilities of comparisons between kinetics and temporal variables in backstroke start performed with and without wedge are presented in Figure 2. It was observed greater force before hands-off, take-off and at hands-off at backstroke start performed with wedge. Force and time reference points have not related with 5 m start time ($P > 0.05$).

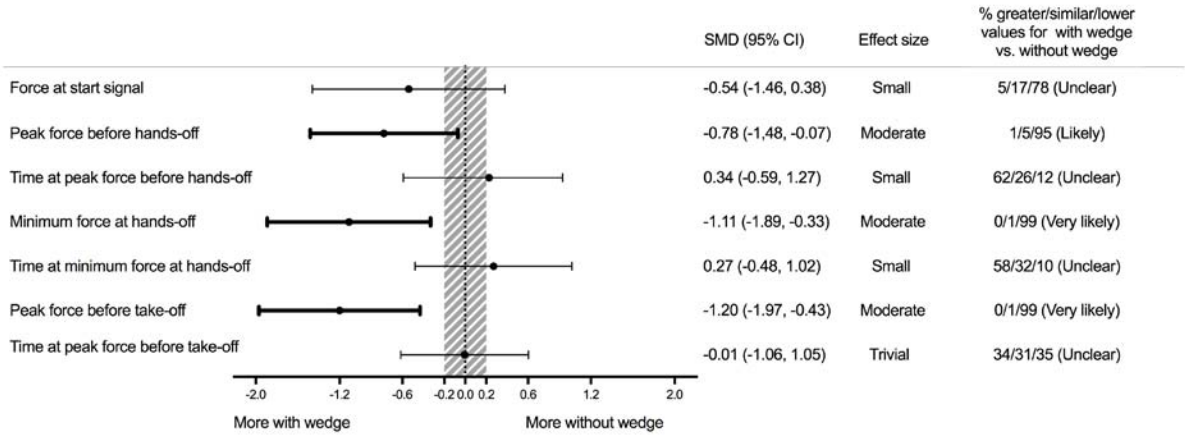


**Figure 2: Standardised mean difference (SMD), 95% CI (confidence intervals), magnitude of effect size and probabilities of comparisons between vertical force and time reference points in backstroke start performed with and without wedge.**

**DISCUSSION:** This study presented the influence of the wedge use on vertical force exerted at the feet and time at critical time reference instants during backstroke start and analysed their associations with 5 m time. Previous studies have mentioned that the wedge was introduced to diminish foot slippage risk (de Jesus et al., 2015; Ikeda et al., 2016), it allows swimmers to generate a vertical force represented by the sum of friction and wedge reaction force (de Jesus et al., 2015). In fact, it was noticed a greater vertical force before and at the hands-off, and preceding the take-off when starting with the introduced device, which has not changed time to achieve these instants. The vertical reaction force at time reference points has not been related with 5 m start time.

In backstroke start technique swimmers have to prioritise the horizontal and vertical forces generation to maintain wall contact while successively moving body segments with a proper steering strategy for propulsion. Despite not measuring reaction forces, previous studies had

already revealed that the wedge inclusion improved kinematic variables as the take-off angle, vertical centre of mass position during flight, vertical velocity at hands-off and water immersion (de Jesus et al., 2015; Ikeda et al., 2016). The generation of vertical forces with the wedge seems to specially improve performance during the flight phase (i.e. toe-off until hands water contact), which might reduce water resistance during flight and entry, improving overall backstroke start performance (Ikeda et al., 2016; Sinistaj et al., 2015).
The lack of associations between force-time curve variables and 5 m time might be explained by the benefits provided by the wedge at backstroke start kinematics during flight and entry actions noticed in previous studies (de Jesus et al., 2015; Ikeda et al., 2016). Based on the current findings, coaches should implement exercises that transfer the kinetic advantages added by the wedge during wall contact instants throughout the flight and entry phases. Despite the importance of the current results, researchers should consider analysing the vertical force-time curve profile at the four available wedge height positions regarding the water surface and the vertical handgrip.

**CONCLUSION:** When using the wedge backstroke start has depicted greater force before hands-off, at hands-off and preceding take-off, although correlations have not been noticed between force and time at time reference points and 5 m time. Vertical force improvements and respective transfer to the flight and entry phase mechanics should be emphasised when backstroke start has been performed with the wedge.

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