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Are the new starting block facilities beneficial for backstroke start performance?

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ABSTRACT
We aimed to analyse the handgrip positioning and the wedge effects on the backstroke start performance and technique. Ten swimmers completed randomly eight 15 m backstroke starts (four with hands on highest horizontal and four on vertical handgrip) performed with and without wedge. One surface and one underwater camera recorded kinematic data. Standardised mean difference (SMD) and 95% confidence intervals (CI) were used. Handgrip positioning did not affect kinematics with and without wedge use. Handgrips horizontally positioned and feet over wedge displayed greater knee angular velocity than without it (SMD = −0.82; 95% CI: −1.56, −0.08). Hands vertically positioned and feet over wedge presented greater take-off angle (SMD = −0.81; 95% CI: −1.55, −0.07), centre of mass (CM) vertical positioning at first water contact (SMD = −0.97; 95% CI: −1.87, −0.07) and CM vertical velocity at CM immersion (SMD = 1.03; 95% CI: 0.08, 1.98) when comparing without wedge use. Swimmers extended the hip previous to the knee and ankle joints, except for the variant with hands vertically positioned without wedge (SMD = 0.75; 95% CI: −0.03, 1.53). Swimmers should preserve biomechanical advantages achieved during flight with variant with hands vertically positioned and wedge throughout entry and underwater phase.

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KEYWORDS
Biomechanics; kinematics; competitive swimming; swimming facility rules; dorsal start

Introduction

An effective swimming start, from the auditory signal to the 15 m mark, can represent up to ~ 30% of the final time in short-distance events (Slawson, Conway, Cossor, Chakravorti, & West, 2013; Vantorre, Chollet, & Seifert, 2014), leading the biomechanists to examine it in detail. Three primary and interdependent phases have contributed to the scanning of the overall start time, the block/wall (11%), flight (5%) and underwater (84%) (Houel, Elipot, André, & Hellard, 2013; Slawson et al., 2013). In 2009 and 2013, the Federation Internationale de Natation (FINA) had authorised facility rule changes that could allow swimmers to take the most out of each backstroke start phase. This fact, combined with the complexity to perform successful backstroke start technique comparing with those for ventral events (de Jesus et al., 2013; Nguyen, Bradshaw, Pease, & Wilson, 2014), had led the scientific community to a growing concern about the backstroke start technique (de Jesus, de Jesus, Fernandes, Vilas-Boas, & Sanders, 2014a).

Recently, studies have been conducted to show the effects of positioning feet entirely immersed and emerged (FINA rules, SW 6.1) on backstroke start performance indicators, regardless handgrips configuration (de Jesus et al., 2013; Nguyen et al., 2014). In those, authors have assessed start phase times, time to reach 5–15 m mark, hip or centre of mass (CM) horizontal and vertical position at auditory signal and at swimmers' hands or head water contact, hip or CM horizontal and vertical velocity at swimmers' hands-off, take-off and hip or CM immersion, take-off and entry angles. Despite researchers having mentioned that many competitive backstrokers have altered their starting technique to place their feet entirely emerged (Nguyen et al., 2014), findings have revealed contradictory results regarding which starting variant should be the most recommended for improving performance (de Jesus et al., 2013; Nguyen et al., 2014).

In 2014, researchers revealed that ~40% of the 2012 London Olympic Games and 2013 Barcelona Swimming World Championships swimmers used the backstroke start variants with feet parallel and partially immersed and hands on the highest horizontal and vertical handgrips (de Jesus, de Jesus, Medeiros, Fernandes, & Vilas-Boas, 2014b). The great acceptance of these variants independent of backstroke event could indicate few biomechanical differences between them. The use of the wedge in those start variants could increase the vertical CM displacement, take-off angle and flight distance, considered decisive for successful backstroke start performance (de Jesus et al., 2011; Nguyen et al., 2014; Takeda, Itoi, Takagi, & Tsubakimoto, 2014). In fact, the wedge obviates part of friction mechanism, allowing better feet wall contact and masking pure static friction effects, which lead to the need of vertical force component hybridisation including the vertical wall reaction force.

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To understand how the handgrips and wedge might affect backstroke start technique, using deterministic model variables (Guimaraes & Hay, 1985) would provide coaches with initial objective evidence about backstroke start variant selection. However, to explain how swimmers organise the most propulsive segment actions when facing those new facilities could reveal technique adaptations for coaches' feedback at backstroke start training sessions. Researchers have highlighted that successful backstroke start performance depends upon greater hip and knee maximal angular velocity and former joint earlier extension (Takeda et al., 2014). Despite authors having shown similar joint couplings regardless of varying rebound jump starting position (Rodacki & Fowler, 2001), it would be expectable that the new wedge could allow swimmers to benefit from a proximal-to-distal lower limb extension sequence (Van Ingen Schenau, 1989). The current study aimed to analyse the handgrip positioning and the wedge use effects on the backstroke start performance and technique.

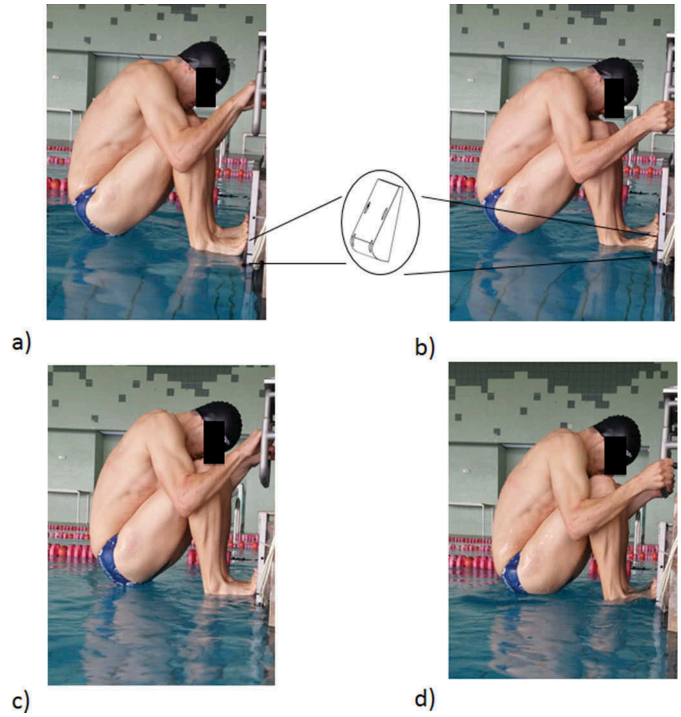

Figure 1. Backstroke start variants positioning at auditory signal. Hands on highest horizontal handgrip and feet positioned over wedge (a). Hands on vertical handgrip and feet positioned over wedge (b). Hands on highest horizontal handgrip and feet positioned without wedge (c). Hands on vertical handgrip and feet positioned without wedge (d).

Methods

Participants

Ten male national-level swimmers (mean and respective 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, mean performance for the 100 m backstroke in 25 m pool of 59.67 ± 2.89 s, representing 78.7 ± 3.6% of the 100 m backstroke short course World Record) volunteered to participate in the study. All participants were healthy (no serious injury or illness occurred in the last 6 months), able-bodied and had participated in national-level competitions. Data collection was approved according to the local research ethics committee, and all experimental procedures conformed to requirements stipulated in the Declaration of Helsinki. Swimmers and parents and/or guardians (when participants were under 18 years) provided informed written consent before data collection.

Backstroke start variants

Two backstroke start variants were studied, both with the feet parallel and partially emerged and the hands on the highest horizontal or vertical handgrip, but performed with (Figure 1a and b, respectively) and without wedge (Figure 1c and d, respectively). The horizontal handgrip was positioned 0.56 m above water level and the vertical was welded to join the lowest (0.43 m above water level) and highest horizontal handgrip. The selection of those two starting variants was based on the high swimmers' percentage that perform backstroke start with feet partially emerged and hands grasping horizontally or vertically the grips (de Jesus et al., 2014b). The starting block, handgrips and wedge pair were custom-built complying with FINA facility rules (FR 2.7 and 2.10), and each wedge pair was positioned 0.04 m above the water level and fixed on an instrumented pool wall.

Starting trials

Swimmers' height and body mass were measured and they answered a questionnaire for background information assessment about their 100 m backstroke start performance. Each swimmer performed a standardised warm up consisting of 600 m front crawl and backstroke swimming, followed by a familiarisation period of each backstroke start variant studied. For that purpose, both variants were verbally described by the research team (complying with FINA rules, SW 6.1), as well as visually depicted by video recordings. Moreover, verbal instruction and feedback were given during familiarisation to ensure that the start variants were performed correctly (Nguyen et al., 2014). Participants were marked at joint centres with black waterproof tape (0.018 m) for tracking during digitising process.

Swimmers participated on two testing sessions of 1 h each in a 25 m indoor and heated (27°C) swimming pool. Between sessions the wedge pair was fixed (or removed) from the instrumented pool wall. Each swimmer randomly performed four maximal 15 m repetitions of each backstroke start variant (with and without wedge), a total of 16 repetitions, with 2 min and 1 h rest in-between each trial and sessions (respectively), with the mean values being calculated and used in subsequent statistical analysis. Starting signals were produced through a starter device (StartTime IV acoustic start, Swiss Timing Ltd, Switzerland) conformed to FINA swimming rules (SW 4.2) and instrumented to simultaneously generate the auditory starting signal and export a light to the video system.

Data collection

Swimmers were videotaped in the sagittal plane for 2D kinematic analysis using a dual media set-up with two stationary and synchronised cameras (HDR CX160E, Sony Electronics Inc., Japan), operating at 50 Hz sampling frequency with 1/250 digital shutter speed. Each camera was placed in a waterproof housing (SPK-CXB, Sony Electronics Inc., Japan) and fixed on a specially designed support for video image-recording. This support was placed at the lateral pool wall, 2.6 m from the starting wall and 6.78 m away from the backstroke start trajectory and perpendicularly to the line of swimmers' motion. Surface and underwater cameras were aligned and placed 0.15 m above and 0.20 m below water level, respectively. A rectangular frame (4 m length [horizontal axis], 2.5 m height [vertical axis] and 2 m width [lateral axis]) was used for starting space calibration and was leaned on the starting pool wall and 0.80 m above the water level with the horizontal axis aligned with the starting direction (cf. de Jesus et al., 2015). A pair of light emitting diodes, visible in each 4.5 m long camera view, was fixed at one of the vertical calibration frame rods.

To enable swimmers' tracking, the following 13 anatomical landmarks were identified on the right side of the body: the vertex of the head (using a swim cap), mid-gonion, acromion, lateral epicondyle of humerus, ulnar styloid process of the wrist, third hand distal phalanx, xyphoid, iliac crest, great trochanter of the femur, lateral epicondyle of the femur, lateral malleolus, calcaneus and first foot distal phalanx. These markers have defined a 10-segment anthropometric model (de Leva, 1996), as used before (de Jesus et al., 2013).

Data processing

The surface and underwater video images were independently digitised frame-by-frame by the same operator using the Ariel Performance Analysis System (Ariel Dynamics Inc., USA) (Gourgoulis et al., 2015). Image coordinates were transformed into 2D object–space coordinates using the Direct Linear Transformation algorithm (Abdel-Aziz & Karara, 1971) with six calibration points, as done before (Barbosa et al., 2015; de Jesus et al., 2013). Following these studies, a 5 Hz cut-off value for data filtering was selected (with a low pass digital filter) done according to residual analysis (residual error vs. cut-off frequency). To determine the accuracy of calibration procedure, the root mean square error of six validation points on the calibration frame, which did not serve as control points, was calculated (respectively for horizontal and vertical axes): (i) 2.32 and 2.22 mm, representing 0.05% and 0.08% of the calibrated space for surface and (ii) 4.72 and 4.59 mm, representing 0.10% and 0.16% of the calibrated space for underwater camera. The accuracy of the digitising procedure of each variable of interest was determined based on data from two repeated digitisations of a randomly selected trial (de Jesus et al., 2013; Figueiredo, Vilas-Boas, Maia, Gonçalves, & Fernandes, 2009), and subsequently tested with the statistical analysis described below.

Data analysis

Backstroke start variants were divided into four phases (adapted from de Jesus et al., 2013; Hohmann, Fehr, Kirsten, & Krueger, 2008): (i) hands-off – between the auditory signal and the instant the swimmers' hand left the handgrips (first positive horizontal swimmers' hand third distal phalanx coordinate); (ii) take-off – from the hands-off until the swimmers' foot left the wall (first positive horizontal swimmers' foot first distal phalanx coordinate); (iii) flight – from the take-off until the swimmers' CM immersion (first negative swimmers' CM vertical coordinate); and (iv) entry – from the final instant of the flight phase until the swimmers' foot immersion (first negative swimmers' foot first distal phalanx vertical coordinate). Linear and angular kinematical variables were (i) absolute hands-off, take-off, flight and entry phase time; (ii) starting time when the middle of the swimmers' head reaches the 5 m distance; (iii) CM horizontal and vertical position at the auditory signal, in relation to the starting pool wall and water surface, respectively; (iv) CM horizontal and vertical position at the swimmers' hand third distal phalanx immersion, in relation to the starting pool wall and water surface, respectively; (v) CM horizontal and vertical velocity at hands-off, take-off, CM and swimmers' full immersion; (vi) take-off angle, formed by the lateral epicondyle of the femur, the lateral malleolus and the horizontal axis; (vii) upper limbs entry angle at the swimmers' hand third distal phalanx immersion (formed by the lateral epicondyle of humerus, the ulnar styloid process of the wrist and the horizontal axis); (viii) upper trunk entry angle at the swimmers' hand third distal phalanx immersion (formed by the acromion, the xyphoid and the horizontal axis); and (ix) maximum hip, knee and ankle angular velocity and respective time. Each individual hip, knee and ankle joint angular velocity curve was normalised from the auditory signal to the CM immersion to assess the respective maximum values and time using a customised module (MatLab R2014, The MathWorks Inc., USA).

Statistical procedures

Data are presented as mean and respective standard deviations. Magnitude-based inference and precision of estimation approach (Hopkins, 2010) was calculated to assess digitising reliability and practical differences in linear and angular kinematical parameters in-between backstroke start variants. Differences were assessed via standardised mean differences (SMD) computed with pooled variance, and respective 95% confidence intervals (CI) (Cohen, 1988). Magnitude thresholds for difference in a mean were described using the following scale: 0–0.2 trivial, >0.2–0.6 small, >0.6–1.2 moderate, >1.2–2.0 large and >2.0 very large (Hopkins, 2010). Effects with 95% CI overlapping zero and/or the smallest worthwhile change (i.e. 0.2 standardised units) were defined as unclear. All statistical computations were performed using a specifically designed Excel spreadsheet (Cumming, 2013). Differences between digitised and re-digitised trials for linear and angular kinematic variables were unclear.

Results

Table I depicts mean and respective standard deviations of linear and angular kinematic parameters for backstroke start variant with hands horizontal and vertically positioned (performed both with and without wedge).

Table II shows SMD and respective 95% CI of comparisons between start variant with hands horizontally and vertically positioned when both performed with and without wedge.

Table I. Mean and respective standard deviations of linear and angular kinematic parameters for backstroke start variant with hands horizontally and vertically positioned performed in both conditions, with and without wedge.

	Horizontal		Vertical	
Variables	With wedge	Without wedge	With wedge	Without wedge
Hands-off phase time (s)	0.56 ± 0.06	0.57 ± 0.05	0.57 ± 0.07	0.57 ± 0.07
Take-off phase time (s)	0.22 ± 0.04	0.21 ± 0.04	0.22 ± 0.04	0.21 ± 0.04
Flight phase time (s)	0.35 ± 0.08	0.33 ± 0.07	0.35 ± 0.08	0.31 ± 0.07
Entry phase time (s)	0.26 ± 0.10	0.26 ± 0.12	0.28 ± 0.07	0.23 ± 0.13
5 m time (s)	1.97 ± 0.14	2.03 ± 0.14	1.97 ± 0.16	2.05 ± 0.14
CM horizontal position at auditory signal (m)	0.39 ± 0.05	0.40 ± 0.03	0.38 ± 0.05	0.40 ± 0.03
CM vertical position at auditory signal (m)	0.28 ± 0.09	0.25 ± 0.08	0.26 ± 0.09	0.24 ± 0.08
CM horizontal position at water contact (m)	1.77 ± 0.20	1.71 ± 0.17	1.77 ± 0.19	1.67 ± 0.16
CM vertical position at water contact (m)	0.33 ± 0.07	0.29 ± 0.05	0.33 ± 0.06	0.27 ± 0.06
CM horizontal velocity at hands-off ($m \cdot s^{-1}$)	1.73 ± 0.34	1.86 ± 0.48	1.80 ± 0.28	1.85 ± 0.40
CM vertical velocity at hands-off ($m \cdot s^{-1}$)	0.70 ± 0.28	0.60 ± 0.29	0.71 ± 0.23	0.56 ± 0.31
CM horizontal velocity at take-off ($m \cdot s^{-1}$)	3.85 ± 0.31	3.68 ± 0.27	3.85 ± 0.37	3.76 ± 0.28
CM vertical velocity at take-off ($m \cdot s^{-1}$)	−0.22 ± 0.46	−0.28 ± 0.42	−0.27 ± 0.43	−0.38 ± 0.38
CM horizontal velocity at CM immersion ($m \cdot s^{-1}$)	3.14 ± 0.39	2.84 ± 0.35	3.16 ± 0.49	2.87 ± 0.15
CM vertical velocity at CM immersion ($m \cdot s^{-1}$)	−2.34 ± 0.26	−2.11 ± 0.29	−2.32 ± 0.26	−2.03 ± 0.29
CM horizontal velocity at full immersion ($m \cdot s^{-1}$)	2.40 ± 0.40	2.28 ± 0.31	2.44 ± 0.36	2.34 ± 0.32
CM vertical velocity at full immersion ($m \cdot s^{-1}$)	−1.61 ± 0.31	−1.62 ± 0.37	−1.57 ± 0.20	−1.61 ± 0.35
Take-off angle (°)	27.24 ± 6.84	23.04 ± 4.88	26.85 ± 6.26	21.31 ± 3.98
Upper limbs entry angle (°)	51.29 ± 9.07	55.12 ± 6.91	52.61 ± 8.88	59.14 ± 10.63
Upper trunk entry angle (°)	31.73 ± 8.67	25.46 ± 6.61	35.79 ± 13.85	24.94 ± 7.60
Maximum hip angular velocity ($rad \cdot s^{-1}$)	7.67 ± 0.72	7.00 ± 1.24	7.76 ± 1.03	6.66 ± 1.29
Maximum hip angular velocity time (%)	54.90 ± 3.22	54.63 ± 6.52	53.41 ± 7.08	56.61 ± 8.21
Maximum knee angular velocity ($rad \cdot s^{-1}$)	15.79 ± 1.72	14.40 ± 0.88	15.53 ± 2.05	14.50 ± 1.45
Maximum knee angular velocity time (%)	62.45 ± 5.01	61.89 ± 5.18	62.30 ± 6.10	63.86 ± 5.39
Maximum ankle angular velocity ($rad \cdot s^{-1}$)	13.76 ± 1.00	13.50 ± 1.93	13.84 ± 0.83	14.25 ± 2.95
Maximum ankle angular velocity time (%)	62.70 ± 5.33	63.11 ± 5.07	61.63 ± 6.07	64.75 ± 5.97

Table II. Standardised mean difference and respective 95% confidence intervals of comparisons between start variant with hands horizontally and vertically positioned performed in both conditions, with and without wedge for linear and angular kinematic parameters that displayed small or greater magnitude of effect (threshold).

	With wedge		Without wedge	
Variables	Horizontal vs. vertical	Magnitude of thresholds	Horizontal vs. vertical	Magnitude of thresholds
Entry phase time	–	–	−0.30 (−1.30, 0.70)	Small
CM horizontal position at water contact	–	–	−0.23 (−1.12, 0.65)	Small
CM vertical position at water contact	–	–	−0.43 (−1.41, 0.54)	Small
CM horizontal velocity at take-off	–	–	0.00 (−0.94, 0.94)	Small
CM vertical velocity at take-off	–	–	−0.21 (−1.07, 0.66)	Small
CM vertical velocity at CM immersion	–	–	0.24 (−0.66, 1.15)	Small
Take-off angle	–	–	−0.32 (−1.15, 0.51)	Small
Upper limbs entry angle	0.53 (−0.67, 1.72)	Small	0.43 (−0.73, 1.59)	Small
Upper trunk entry angle	0.43 (−0.73, 1.59)	Small	–	–
Maximum hip angular velocity	–	–	−0.25 (−1.17, 0.68)	Small
Maximum hip angular velocity time	−0.40 (−1.92, 1.12)	Small	0.26 (−0.77, 1.29)	Small
Maximum knee angular velocity	−0.21 (−1.17, 0.75)	Small	–	–
Maximum knee angular velocity time	–	–	0.32 (−0.60, 1.25)	Small
Maximum ankle angular velocity	–	–	0.25 (−0.86, 1.36)	Small
Maximum ankle angular velocity time	–	–	0.28 (−0.72, 1.27)	Small

Despite only comparisons with small magnitude of effect being displayed, magnitude of effects ranged from trivial to small and all differences were unclear.

Table III shows SMD and respective 95% CI of comparisons between starting conditions (with and without wedge) for start variants with hands horizontally and vertically positioned. Only comparisons with small to greater magnitude of effect were shown, and few variables registered clear differences, being all with moderate magnitude of effect. Start variant with hands horizontally positioned and with wedge depicted greater knee angular velocity. Start variant with hands vertically positioned performed with the wedge displayed greater CM vertical position at first water contact, take-off angle and CM vertical velocity at CM immersion.

Figure 2 shows SMD and respective 95% CI of comparisons between times of maximum hip, knee and ankle joint angular velocity in the start variants performed with hands horizontally and vertically positioned (with and without wedge). Comparisons that revealed trivial magnitude of effect were excluded from Figure 2. It was observed that the hip was the first joint to be extended (magnitude of effects ranging from moderate to very large), followed by the simultaneous knee and ankle extension, excepting the variant with upper limbs vertically positioned performed without wedge.

Table III. Standardized mean difference and respective 95% confidence intervals of comparisons between wedge conditions (with and without) in both start variants, horizontal and vertical handgrips positioning for linear and angular kinematic parameters that displayed small or greater magnitude of effect (threshold).

	Horizontal		Vertical	
Variables	With vs. without wedge	Magnitude of thresholds	With vs. without wedge	Magnitude of thresholds
Take off phase time	−0.24 (−1.08, 0.58)	Small	−0.35 (−1.20, 0.49)	Small
Flight phase time	−0.24 (−1.08, 0.58)	Small	−0.35 (−1.20, 0.49)	Small
Entry phase time	–	–	−0.69 (−2.04, 0.66)	Moderate
5 m time	0.42 (−0.47, 1.31)	Small	0.47 (−0.37, 1.30)	Small
CM horizontal position at starting signal	0.30 (−0.40, 1.00)	Small	0.45 (−0.33, 1.23)	Small
CM vertical position at starting signal	−0.29 (−1.11, 0.54)	Small	0.25 (−1.10, 0.59)	Small
CM horizontal position at water contact	−0.29 (−1.10, 0.53)	Small	−0.47 (−1.28, 0.35)	Small
CM vertical position at water contact	−0.51 (−1.28, 0.27)	Small	−0.97 (−1.87, −0.07)	Moderate
CM horizontal velocity at hands-off	0.35 (−0.76, 1.46)	Small	–	–
CM vertical velocity at hands-off	−0.33 (−1.24, 0.57)	Small	−0.59 (−1.68, 0.50)	Small
CM horizontal velocity at take-off	−0.49 (−1.31, 0.34)	Small	−0.22 (−1.01, 0.56)	Small
CM vertical velocity at take-off	–	–	−0.23 (−1.07, 0.61)	Small
CM horizontal velocity at CM immersion	−0.72 (−1.57, 0.12)	Moderate	−0.55 (−1.22, 0.13)	Moderate
CM vertical velocity at CM immersion	0.81 (−0.14, 1.76)	Moderate	1.03 (0.08, 1.98)	Moderate
CM horizontal velocity at body immersion	−0.27 (−1.07, 0.52)	Small	−0.25 (−1.10, 0.59)	Small
Take off angle	−0.56 (−1.33, 0.20)	Small	−0.81 (−1.55, −0.07)	Moderate
Upper limbs entry angle	0.39 (−0.40, 1.17)	Small	0.67 (−0.32, 1.66)	Moderate
Upper trunk entry angle	−0.66 (−1.45, 0.13)	Moderate	−0.72 (−1.43, 0.00)	Moderate
Maximum hip angular velocity	−0.85 (−2.16, 0.46)	Moderate	−0.97 (−1.98, 0.05)	Moderate
Maximum hip angular velocity time	–	–	0.39 (−0.58, 1.37)	Small
Maximum knee angular velocity	−0.82 (−1.56, −0.08)	Moderate	−0.48 (−1.24, 0.28)	Small
Maximum knee angular velocity time	–	–	0.22 (−0.62, 1.06)	Small
Maximum ankle angular velocity	–	–	0.32 (−1.87, 2.51)	Small
Maximum ankle angular velocity time	–	–	0.45 (−0.44, 1.33)	Small

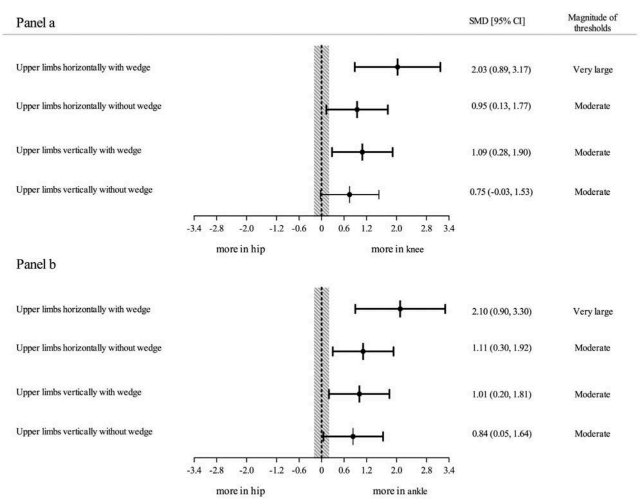

Figure 2. SMD and respective 95% CI of comparisons between time at maximum joint velocity in backstroke start variant with hands horizontally and vertically positioned performed in both conditions, with and without wedge, whose magnitude of effect (threshold) was small or greater. Comparison between time at maximum hip and knee angular velocity (a). Comparison between time at maximum hip and ankle angular velocity (b).

Discussion

The current study is the first that analysed the handgrip positioning and the wedge use effects on the backstroke start performance and technique. Main findings have revealed that (i) different handgrips positioning had not affected the linear and angular kinematic parameters; (ii) the variant with hands horizontally positioned displayed greater knee extension angular velocity with the wedge; (iii) the start variant with hands vertically positioned increased the take-off angle, CM vertical position at first water contact and CM vertical velocity at CM water immersion with the wedge; and (iv) the wedge use had not implied a proximal-to-distal lower limb joint extension sequence when swimmers starting with hands horizontally or vertically positioned, being the hip the first joint to be extended, excepting the variant with hands vertically positioned performed without the wedge. The above-mentioned findings partially confirm the assumptions already established in this study since it was presumed that the handgrips would not affect backstroke start kinematics and the wedge use would increase vertical CM displacement, take-off angle, flight distance, and consequently, reducing start time through a proximal-to-distal lower limb joint extension sequence.

After the implementation of the current starting block configuration (Omega OSB11, Swiss Timing, Ltd, Switzerland), which has been depicted in ventral start studies (Slawson et al., 2013; Takeda, Takagi, & Tsubakimoto, 2012), researchers have observed that, regardless the competitive event, elite swimmers have often adopted the start variant with feet positioned partially emerged and hands on the highest horizontal and vertical handgrips (de Jesus et al., 2014b). As expected, the handgrips positioning had not changed backstroke start performance and swimmers had used similar lower limb joint extension couplings to propel themselves out of the starting wall. In fact, starting performance seems to be successful as long as initial set positioning is sufficiently close to the preferred backstroke start variant, as previously noticed in rebound jumping (Rodacki & Fowler, 2001). Previous ventral start studies revealed that several similar start styles could lead to similar start performance (Seifert et al., 2010; Vantorre et al., 2014). It is important to note that previous researches considering the start variant with feet parallel and positioned entirely emerged (without wedge) have shown swimmers' CM or hip starting position ~0.20 m above the water level (de Jesus et al., 2013; Nguyen et al., 2014). In the current study, the two start variants performed with and without wedge registered mean values of CM vertical coordinate at starting position ranging from 0.24 to 0.28 m. Therefore, it is suggested that both handgrip configurations performed with and without wedge contribute to a better-suited CM setup position, which is considered a backstroke start performance determinant (Nguyen et al., 2014; Takeda et al., 2014).

The wedge implementation is based upon previous biomechanical advantages reported in studies analysing the outdated start variants performed with the gutter supporting (for a more detailed description, see de Jesus et al., 2014a). Backstrokers who hold themselves on the wedge might benefit from greater vertical force that can provide a less resistant CM aerial pathway reducing swimmers' deceleration (de Jesus et al., 2013; Takeda et al., 2014). In this study, the wedge use increased the knee extension angular velocity when swimmers performed start variants with hands horizontally positioned, which did not imply a greater CM vertical positioning, as previously reported (Takeda et al., 2014). Contrarily, the wedge use in the starting variant with hands vertically positioned depicted greater take-off angle, CM vertical position at first water contact and CM vertical velocity at CM immersion, considered decisive to reduce start time (de Jesus et al., 2011; Guimaraes & Hay, 1985). Based on these evidence, it seems that the use of the wedge combined with the vertical handgrips might allow swimmers obtaining biomechanical advantages that, if sustained throughout the underwater phases, could result in reduced start time, as previously recommended (de Jesus et al., 2013). Despite the confidence intervals having indicated unclear 5 m start time differences between wedge conditions in both start variants, it could be evidenced clear feet support benefits in backstroke start performance if a larger sample had been studied. In addition, it would take longer for proficient competitive swimmers to familiarise themselves enough to improve their start performance using the new facilities (Nguyen et al. (2014))

The underwater phase impact on overall start time is well reported (de Jesus et al., 2014a; Vantorre et al., 2014); however, the wall/block phase determines what happens in the flight and, subsequently, in the underwater phase (Slawson et al., 2013; Takeda, Ichikawa, Takagi, & Tsubakimoto, 2009; Vantorre et al., 2014). In the light of this start phases interdependency, the authors have attempted to clarify coaches how swimmers coordinate their lower limb joint actions to generate proper take-off angle with less resistant flight and entry phases, and consequently, improving overall backstroke start performance (Takeda et al., 2014). For those authors, proficient backstrokers perform the start extending the hip prior to the knee joint with high angular velocity. Despite most of the current findings corroborating previous backstroke start (Takeda et al., 2014) and rebound jump studies (Rodacki & Fowler, 2001) regarding the anticipated hip join extension, the improved feet indentation provided by the wedge had not resulted in a clear proximal-to-distal joint extension sequence. Much research has suggested that throwing, striking, jumping and kicking skills all exhibit aspects of proximal-to-distal sequencing to produce the largest possible velocity at the end of a linked chain of segments (Marshall & Elliott, 2000; Van Ingen Schenau, 1989). The simultaneous knee and ankle joint extension observed in the current study seems to be explained by a swimmer's strategy to deal with short take-off angle to generate a maximum horizontal force before swimmers' feet contact to the wall (de Jesus et al., 2013; Hohmann et al., 2008). Indeed, the authors have mentioned that different explosive movements might impose constraints of an external and/or anatomical nature, which could imply the requirements of either a sequential or simultaneous strategy (Ravn et al., 1999). In addition, those authors have indicated that the level of trunk inclination explains the choice of a sequential or simultaneous strategy (Ravn et al., 1999).

Notwithstanding the originality and relevance of the current data, limitations should be addressed. Firstly, the sample size, which undermines the confidence intervals and, therefore, the precision of the presented effect size estimations. Ten participants were selected in the current study, which is a reasonable number in experiments that require swimmers' availability for familiarisation and testing protocols using complex data methodology (Houel et al., 2013; Nguyen et al., 2014; Takeda et al., 2009). Secondly, the familiarisation period followed previous study protocols and strategies were implemented to reduce the start variant bias (e.g. Nguyen et al., 2014). However, future studies should consider taking a longer training period to allow swimmers to improve their performance using the new starting block facilities, as previously suggested (Nguyen et al., 2014; Takeda et al., 2012). Lastly, the recent approved wedge can be adjusted in five heights related to the water level, as the ventral start back plate (Takeda et al., 2012), and in the current study only the highest positioning was chosen (i.e. 0.04 m above water level) due to the high percentage of swimmers that prefer to perform backstroke start with feet above water level (de Jesus et al., 2014b). Future studies should investigate in detail how swimmers overcome the task constraints imposed by the combination of different handgrip and wedge positioning from the auditory signal to the 15 m mark.

Conclusions

The current study analysed the handgrips configuration and wedge effects on backstroke start performance and technique. The results have shown that positioning the hands on the highest horizontal or vertical handgrip had not affected backstroke start performance and the intralimb coordinative strategy before take-off propulsion. However, the wedge use revealed biomechanical advantages during the flight phase when combined to the vertical handgrip, as greater take-off angle, CM vertical positioning and CM vertical velocity at partial immersion, even when swimmers were using similar lower limb coordination. From a practical perspective, the present results would suggest that swimmers could take backstroke start performance advantages if they used the variant with vertical handgrip and the wedge. However, swimmers should maintain the biomechanical advantages resulting from a more vertical flight pathway throughout the entry and underwater phase for successful start performance. In spite of the apparent restricted lower limb coordination strategy disregarding the start variant and wedge condition (with or without), coaches should consider training with other wedge positioning to decide upon which start variant is the most appropriated for each swimmer.

Disclosure statement

No potential conflict of interest was reported by the authors.

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