Concurrent validity and test-retest reliability of an elite tracking system to assess swimming performance variables.

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Abstract

The TritonWear® technology is designed to aid swimming and coaching practice through the measurement and data feedback of eight key performance skills; split time, stroke count, speed, stroke rate, distance per stroke, turn time, time underwater and stroke index. There is yet to be any literature published that into the reliability and validity of this technology, limiting the extent to which its use can be justified. The present study set out to determine the inter-trial reliability of both the TritonWear® device and video analyses, and the concurrent validity of the TritonWear® device through comparison to video analysis across two trials. The a-priori goal of this study was to specifically comment on the usefulness of this wearable technology to coaches who are seeking to increase split times (swimming velocity) as well as coach athletes to improve upon highly complex skills such as turn-times. Twenty swimmers (age 16.29 ± 2.77 years) and their parent or guardian consented to the completion of two 100 metre swims (4 x 25m) at race-pace for either freestyle or breaststroke on different days whilst wearing the TritonWear® device. After 48 hours, swimmers repeated the trial at race pace, both trials were videoed above and below water. The coefficient of variation (CV) and 95 % limits of agreement methods were used to assess reliability on both the TritonWear® device and video footage data. For freestyle; results were reported as reliable for all but one variable (TritonWear® - time underwater, CV = 26.68 %) with all results consistently below 8% (CV = 1.84 % to 7.03 %). For breaststroke; results were reported as reliable for all but three variables; TritonWear®; time underwater CV = 26.68 %; stroke index = 19.09 %; distance per stroke = 17.03 %, and video; stroke index = 14.02 %. All other results were consistently below 9 % (CV = 1.10% to 8.97 %). The most reliable limits of agreement (LOA) variables were turn time (0.01 seconds ± 0.13 seconds) for freestyle and speed for breaststroke (0.03 ± 0.22). In relation to the analytical goals set, the present study shows that the TritonWear® device is reliable for the measurement of split time, turn time and speed for high level junior swimmers.

Keywords: *TritonWear®, video analyses, split time, turn time, comparison of methods*

Introduction:

Swimming at the elite level is competitive, where marginal advantages in training prescription can transfer into improvements in competition times, increasing an athlete's chance of success (James, Davey, & Rice, 2004). Coaches and athletes often search for performance-enhancing opportunities to support their training programme; one emerging strategy is to use quantifiable data analyses through tracking devices to measure both skill and technical development. Such analyses are usually conducted using either video or sensor-based data collection (Beanland, Main, Aisbett, Gastin, & Netto, 2014). Video analyses are generally considered to be the 'gold standard' method of analysing swimming performance (Ceseracciu, Sawacha, Fantozzi, Cortesi, Gatta, Corazza & Cobelli, 2011) and are currently the most-used method for obtaining quantitative information for swimmers (Smith, Norris, & Hogg, 2002). Cameras positioned both above and below the water are used to assess a variety of swimming metrics, such as velocity profiling (Komar, Leprêtre, Alberty, Vantorre, Fernandes, Hellard et al., 2012), and joint angular kinematics (Sanders, 2007).

Video analysis of swimming performance is complex and has limitations; for example, researchers have noted parallax error and water turbulence, which can alter or obscure the video images (Payton, 2008). In addition, the digitisation and data analysis process can be arduous and time-consuming; possibly resulting in high magnitudes of error occurring during data collection and analyses; Gourgoulis, Aggeloussis, Kasimatis, Vezos, Boli, & Mavromatis, (2008) reported underwater recording root mean square errors up to reporting up to 1.28 %. Such errors could result in poorly informed coaching conclusions (Phillips, Farrow, Ball, & Helmer, 2013), and can directly limit the application of video analyses in training and competition (Magalhaes, Vannozzi, Gatta, & Fantozzi, 2015). When it is correctly interpreted, data collected through video footage can provide the coach with both qualitative and quantitative feedback, which can be effectively used to aid both training and competition (Smith, Norris, & Hogg 2002). One study found that approximately three quarters of coaches in the United States of America are currently using video analysis monthly, with most coaches showing a significant over representation of qualitative analyses and a lack of representation of quantitative analyses, as shown through a chi-square goodness-of-fit test (X2 = 35.93) (Mooney, Corley, Godfrey, Osborough, Newell, Quinlan, & ÓLaighin, 2016). The apparent reliance on qualitative measures has been suggested by these researchers to be due to the low cost and easily implementable nature, especially regarding biomechanical analysis. However, it has been argued by Knudson (2007) that for meaningful analyses to occur, the coach must have an outstanding level of expertise regarding biomechanical knowledge and understanding. This information suggests that there is a clear requirement for an alternative performance analysis option that is reliable, valid, and can be implemented easily into the training regime of high level swimmers.

Technological advances are providing coaches and athletes with alternative options through the development of wearable and water-proof microelectromechanical systems (MEMS) (Callaway, Cobb, & Jones, 2009). Several researchers have developed and used MEMS technologies to analyse key performance objectives within their studies (Dadashi, Crettenand, Millet, Seifert, Komar, & Aminian, 2013; Davey, Anderson, & James, 2008; Ohgi, Ichikawa, Homma, & Miyaji 2003); however, Magalhaes et al. (2015) noticed a gap in the literature as many of the algorithms used are different, which is due to a wide variety of sensors and sensor attachments. The TritonWear® technology claims to accurately measure a range of metrics for both speed and stroke efficiency, using a head mounted device. Use of a head-worn sensor has advantages, firstly; overall motion of the swimmer's body can be recorded, secondly; Lecoutere, and Puers, (2014) noted that swimmers experience fewer proprioceptive changes compared to when the sensors are located on other body parts such as the wrist. In their study, a miniaturised triaxial accelerometer and gyroscope was devised to automatically calculate and record stroke type, stroke rate and distance per stroke during a 200 medley. The research was deemed successful by the researchers who claimed to have collected raw accelerometer and gyroscope data. However, there was no mention as to whether this data was either reliable or valid. If the data is to be extrapolated into commercial use, such information is crucial to obtain. In addition, there is no clarification as to how many subjects were tested in the research, which leads to questioning around how this data might have differed, had there been a larger sample size of people with varied swimming styles and biomechanical properties. Mooney et al (2016) state that there is a need to further investigation into the use of a head-worn tracking device for swimming performance, and advise that thorough analyses should be carried out.

The TritonWear® device is a technologically advanced, head-mounted swimming sensor that is currently on the market. Its reliability has not yet been tested, somewhat limiting the justification for swimming teams to use the technology to assess the discussed performance parameters. As there is yet to be any published data on the validity of the TritonWear® device, the justification for its use to reliably enhance performance is limited. To determine changes in performance using this device, its reliability must first be established. TritonWear® claim to accurately and reliably measure the swimming performance of metrics; split time, stroke count, speed, stroke rate, distance per stroke, turn time, time underwater and stroke index (Lehary, 2015).

Split time and speed are two of the most crucial variables that will be assessed. When coaches test for performance improvements, it will often be the velocity that the athlete has swum over a set distance on two or more trials that will be the key performance indicator (Corley, Mooney, Quinlan, & Laighin, 2015). Stroke count is measured using the movement of the swimmer's head as they progress through the water. Turn-time is the preferred method of directional change, a tumble-turn is used in freestyle swimming, and an open-turn in breaststroke (Maglischo, 2003). Technical mastery of a tumble turn is complex, with several variables that need to be accounted for (Lee, Leadbetter, Ohgi, Thiel, Burkett & James, 2011), including two rotations of the body; one in the transverse axis and one in the longitudinal axis (Maglischo, 2003). Stroke rate is one of the most commonly assessed variables in the literature (Mooney, Corley, Godfrey, Osborough, Newell, Quinlan, & ÓLaighin, 2016), the device will recognise a unique signal profile by the motion of the swimmer's head. For instance, freestyle stroke rate will be determined by the rolling motion of the head which is required for breathing, and breaststroke is recognised due to the unique upwards and downwards motion of the swimmer's head,

The devices that are used most frequently attach to the swimmer's wrist or back, both of which use a similar method to calculate the sum of acceleration peaks for each lap (Chakravorti, Le Sage, Slawson, Conway, & West, 2013). Beanland, Main, Aisbett, Gastin, & Netto (2014) studied velocity and stroke count with twenty-one sub-elite swimmers using a head-mounted global positioning system (GPS) device and an integrated tri-axial accelerometer against video analysis. They reported high accuracy for stroke count readings in butterfly (R = 1.00) and breaststroke (R = 0.99) but not for freestyle. Freestyle stroke count was not measured, as initial assessments of the accelerometer signals showed no clear recognisable pattern for this stroke, which is likely due to the head mounted sensor, as other studies could identify freestyle stroke count when devices have been attached to the wrist (Siirtola, Laurinen, Röning, & Kinnunen, 2011) and lower back (Ichikawa, Ohgi, Miyaji, & Nomura, (2006). As one of the most crucial performance indicators, reliable measurement of swimming velocity is of critical importance in performance testing (Dadashi, Crettenand, Millet, & Aminian, 2012; Stamm, James, & Thiel, 2013; Dadashi, Millet, & Aminian, 2015; Beanland, Main, Aisbett, Gastin, & Netto, 2014; Bächlin, & Tröster, 2012).

The variables discussed are key performance markers in a sport where minute improvement can be the difference between success and failure. If a reliable and valid tracking device can instantly provide the coach with useable information, there is a clear opportunity to coach and improve swimming performance using accurate and reliable quantitative information. To provide coaches with such feedback, Atkinson and Nevill (1998) suggest that the meaningfulness of repeated tests can be quantified using 'analytical goals'. Analytical goals require the researcher to decide if the 95 % limits of agreement are acceptable enough for the outcomes of a test to be of practical use.

Split times are key performance indicators analysed by coaches to measure improvement in athletes, usually following a period of training (Garland Fritzdorf, Hibbs & Kleshnev, 2009). One important analytical goal in relation to this, is to take into consideration how much improvement each athlete from the sample population is likely to make during a training period of 12 months. A period of 12 months was chosen, as the most competitive event of the season for these athletes occurs at the same time each year, following which a new periodised programme will begin. The analytical goal therefore, was that the average 95 % limits of agreement and coefficient of variation are less than that of the average yearly improvement of split time, for the stroke and distance that each swimmer performed in testing. If the percentage of improvement is lower for yearly improvement than data from reliability and validity testing shows, a coach cannot conceivably conclude that the athlete has indeed improved, as it is possible that any improvement shown in the data is simply down to the variation between devices (error) or day to day variation of the athletes (biological error).

Turn time has been identified in the literature as a key indicator of race performance (King & Yeadon, 2004). Chow, Hay, Wilson, and Imel (1984) reported strong relationships ($R = 0.59 – 0.73$) between split times and turning efficiency. Turn time is a crucial skill to improve for both longer (Chakravorti, Slawson, Cossor, Conway, & West, 2012) and shorter swimming events (Lee, Leadbetter, Ohgi, Thiel, Burkett, & James, 2011), with Thayer and Hay (1984) estimating that time taken to turn is approximately equal to one-third of the time taken to complete the swimming set. Turning technique is a highly complex skill (Lyttle, Blanksby, Elliott, & Lloyd, 1998), with great variations of technique between individuals (Chu, Luk, & Hong, 1999). It is therefore crucial that for swimmers using technology to make improvements to performance; that a device claiming to provide reliable feedback is tested and validated. The evidence strongly suggests that turn performance is a crucial consideration for coaching swimmers (Mason & Cossor, 2001), therefore an analytical goal was set to determine how reliable the 'turn time' information is and to what extent coaches of young swimmers might be able to use this information to the advantage of the population of swimmers that has been tested.

The present study principally aimed to accurately and extensively evaluate the reliability and concurrent validity of the TritonWear device for the eight variables that have been discussed. Additionally, through the analyses of reliability data of the device, as well as video footage; this study aimed to add some clarification to the notion that video analysis is itself a reliable method of quantitatively processing data that is useful to young swimmers. With the use of analytical goals, this study aims to specifically comment on the usefulness of this wearable technology to coaches who are seeking to increase split times (swimming velocity) as well as coach athletes to improve upon highly complex skills such as turn-times. Finally, this study aims to explore the extent to which experience and ability of the individual using the device changes the reliability and validity of its use. In doing so, this study aimed to provide coaches who use the TritonWear device with some information that is relevant and useable in relation to the population of athletes that has been tested.

Methods

Design and procedure

This present study was a quantitative, test-retest reliability and concurrent validity study assessing the TritonWear® device against the following dependant variables; speed, split time, turn time, time underwater, stroke count, stroke rate, distance per stroke, and stroke index.

Participants completed two 100m swims (4 x 25 m) at race pace for either freestyle or breast stroke on different days whilst wearing the TritonWear® device. After a period of 48 hours, swimmers returned to the pool to swim the same stroke, in the same order, over the same distance, at race pace. Athletes were required to attend both testing sessions, each test lasted no longer than 20 min including warm up. The warm up consisted of a 15 min swimming specific routine, which included; raising of heart rate and body temperature through light swimming of the given stroke for 5 min, upper and lower body activation and mobilisation exercises as well as potentiation swims progressively building to 'race pace' over 6 lengths. Participants then exited the pool to have the TritonWear® device fitted directly inferior to the inion, on the occipital bone, as advised by the TritonWear® manual guidelines (Lehary 2015). Swimming data was collected on the TritonWear® device through the TritonWear® online platform. The two sets of data were then compared and a test re-test reliability analysis took place. The data was also compared to video analysis using the SwimPro® system below water and 'Coaches Eye' above water to measure the concurrent validity of the test. Currently, video analysis is the gold-standard measure to accurately assess the discussed variables (Ceseracciu, Sawacha, Fantozzi, Cortesi, Gatta, Corazza, et al 2011). In line with FINA recommendations, water temperature was controlled to be equal for both trials (25 °C). Weather temperature was within one degree from trial 1 (34 °C) to trial 2 (35 °C) with a humidity of 64 % in trial 1 and 62% in trial 2, as measured by the schools 'in house' temperature system.

Participants

Twenty male and female swimmers (age 16 ± 2.77 years) and their parent/guardian gave consent to participate in the present study. Participants were excluded if they or their parent/guardian did not wish to provide full consent. Trials were spaced 48 hours apart, with athletes asked not to exercise on testing days and to follow their usual dietary habits. Ethical approval was granted by the St Mary's university ethics sub-committee.

TritonWear and Video Systems

The components of the waterproof sensor unit include; a 9-axis inertial measurement unit; including a 3-Axis digital accelerometer, a 3-axis digital gyroscope, and a 3-axis digital magnetometer, a micro-controller, a wireless module to transmit calculated metrics to the hub, a clock to synchronise timing and a lithium ion polymer battery with an internal battery charging unit. The tracker contains three axes which read the oscillation data from both the accelerometer and the gyroscope. Oscillation data will differ depending on which stroke is being performed, due to the Euler Angles (pitch, yaw and roll). During the freestyle stroke, the rolling motion of the swimmer's head will be picked up in the 'roll readings' on the tracking device. Breaststroke produces wave-like oscillations that are read by the device in the 'pitch' measurements; whenever the unit's pitch reading surpasses a certain limit, a stroke will be counted.

Regarding the metrics analysed; time underwater is the time taken for the swimmer to break out of the water following their push off the wall. The tracking device receives signals to show when the time underwater measurement ends and occurs after the breakout of the water, before the first stroke is taken. The measurement is calculated by multiplying the individual's average velocity over the length with the time of the breakout event. Distance per stroke (DPS) is calculated using data from two other metrics; stroke count and distance underwater. An average distance per stroke per length of the pool is measured by subtracting the distance underwater by the length of the pool - in this instance twenty-five metres - and then dividing that number by the total number of strokes for that length (Length of pool – distance underwater) / number of strokes. Stroke rate is measured by calculating the distance underwater and the number of strokes per length. Time underwater is subtracted from the total time taken to complete that length, which calculates the total amount of time that the swimmer spent stroking in that length. This stroke rate is then found by dividing the time stroking by the number of strokes in that length, this number is then converted to a format representing strokes per minute. Speed is determined by dividing the length of the pool by the time taken to swim it, in relation to swimming velocity (speed), 'stroke index' is the metric used to highlight the swimmers stroke efficiency. The calculation is distance per stroke x speed x cycle multiplier. For freestyle, the cycle multiplier is two strokes for one cycle, for breaststroke, one stroke is equal to one cycle. Simply, the higher the stroke index, the more efficient the technique. Theoretically, less energy should be required when a swimmer travels faster with fewer strokes.

Two 'wall clam' and two 'claw cam' SwimPro® cameras were used with supporting software for video analyses. Each camera has 1080p @ 1 MP/s, with a shutter speed of up to 1/10000 seconds. The camera hardware consists of 120 gb SSD with 'SuperSpeed' download capacity (60 mb/s) and a HDMI mini display port TV and computer monitor output. The trials were videoed above and below water using four SwimPro® cameras, each capturing 30 progressive video frames per second. Above water video will be recorded using an iPad and CoachesEye® analyses software, also at 30 frames per second. For thorough technical examination, it's imperative that both above and below cameras are used to fully observe the swimmer's movements, minimising light refraction and the effect of bubbles and splashes obscuring the view are key factors to take into consideration (Gourgoulis, Aggeloussis, Kasimatis, Vezos, Boli, & Mavromatis, 2008). Regarding camera quality, Payton (2008) recommends that using a frame rate of 25-50 Hz and a shutter speed between 1/350-1/750 seconds for maximum image quality. The video footage was manually reviewed by one assessor, the four cameras were synchronised with each other using the SwimPro platform, for concurrent validity; the recorded data sets on the TritonWear platform were compared directly to those of the video analyses.

Statistical Analyses

Concurrent validity and reliability was assessed using a 95 % limits of agreement (Bland and Altman, 1986) and coefficient of variation (Atkinson & Nevill, 1998). Paired sampled t-tests were used to calculate biases between the TritonWear® device and Video footage (validity) and to compare data of the two trials (reliability). Statistical significance was set at $P < 0.05$ for all dependant variables. The Shapiro-Wilk test measured the normality of differences between tests and the Pearson product-moment correlation was used to measure the strength of a linear association between variables. Data has been reported using averages (means) as well as standard deviations, and was analysed using SPSS (SPSS v.22; Inc., Chicago, IL).

Results

The CV method was used to assess reliability on both the TritonWear® device and video footage data (Table 1). For freestyle; results were reported as reliable for all but one variable (TritonWear - time underwater, CV = 26.68 %) with all results consistently below 8% (CV 1.84 % to 7.03 %). For breaststroke; results were reported as reliable for all but three variables; TritonWear; time underwater = 30.90 %; stroke index = 19.09 %; distance per stroke = 17.03 %, and video; stroke index = 14.02 %. All other results were consistently below 9 % (CV = 1.10 % to 8.97 %).

Using the paired-sample t-test (Table II) to calculate bias. TritonWear® Measurements of stroke count, stroke rate, distance per stroke, turn time, time underwater and stroke index demonstrated no significant differences (*P* > 0.05) for freestyle trials one and two. Measurements of split time (*P* = 0.01) and speed (*P* = 0.03) demonstrated systematic bias, with the second trial being slower across participants from trial 1 to trial 2. The same was apparent with the video data, with split time (*P* = 0.01) and speed (*P* = 0.01) showing systematic bias, in addition stroke index (*P* = 0.00) also demonstrated bias, all other measurements demonstrated no significant differences.

TritonWear® Measurements of split time, stroke count, speed, distance per stroke, turn time, time underwater and stroke index demonstrated no significant differences (*P* > 0.05) for breaststroke trials one and two. Measurements of stroke rate (*P* = 0.02) demonstrated systematic bias. Video data showed that all measurements demonstrated no significant differences (*P* > 0.05) except for stroke index (*P* = 0.03), which showed systematic bias.

Using the 95 % LOA method, mean differences between trials for both freestyle and breaststroke are shown in Table 1 for both the TritonWear® device and the video analysis.

Mean differences between trials ranged from 0.00 to 0.55 for Triton freestyle, 0.03 to 0.7 for Triton breaststroke, 0.01 to 0.13 for video freestyle and 0.013 for video breaststroke. Measurements of greatest reliability were Speed for Triton freestyle (95% LOA = 0.00 ± 0.07, CV 1.84 %), split time for triton breaststroke (95 % LOA 0.16 ± 1.20), CV 1.98 %, speed for video freestyle (95 % LOA = 0.05 ± 0.08, CV 2.03 %) and split time for video breaststroke (95 % LOA = -0.07 ± 0.66, CV 1.10 %).

Based on data from competitive swim meets, average improvement for the freestyle group over one calendar year was 3.1% or 2.09 seconds. Based on 95 % limits of agreement validity data, there was an average 0.66 second underestimation (0.49 + 0.83 / 2) reported for split times. Reliability data of the TritonWear® device showed an error of -0.55 with a 95 % LOA of 0.94, translating to a 0.39 second underestimation of split time. The mean difference in split times between trial 1 and trial 2 was 0.55 seconds. Average improvement for the breaststroke group over 12 months was 3.97 % or 3.32 seconds. Based on 95 % limits of agreement validity data, there was an average 0.58 second underestimation (0.62 + 0.53 / 2) reported for split times. Reliability data of the TritonWear® device showed an error of -0.16 with a 95 % LOA of 1.20, translating to a 1.04 second underestimation of split times.

Based on 95 % limits of agreement freestyle validity data, there was an average 0.27 s underestimation (0.32 + 0.22 / 2) reported for turn times. Reliability data of the TritonWear device showed an error of 0.006 with a 95 % LOA of 0.13, translating to a 0.14 s underestimation of turn time. CV for TritonWear® freestyle turn times was 4.2 %, which was reported as reliable. Breaststroke validity data showed that there was an average 0.59 s underestimation (0.72 + 0.45 / 2) reported for turn times. Reliability data of the TritonWear® device showed an error of 0.13 with a 95 % LOA of 0.37, translating to a 0.5 s underestimation of turn time. CV for TritonWear® breaststroke turn times was 8.97 %, which was reported as reliable.

Split time reliability data from the TritonWear® device found that the fastest five swimmers (CV = 1.5, LOA = 0.67) were more consistent than the slowest five (CV = 1.92, LOA = 1.02) similarly, for breaststroke; the fastest five swimmers (CV = 0.96, LOA = 0.54) were less erroneous than the slowest five (CV = 1.66, LOA = 1.09). Validity data confirms this trend, freestyle fastest swimmers (CV = 0.49, LOA = 0.22), and slowest (CV = 1.28, LOA = 0.69), and breaststroke fastest (CV = 0.54, LOA = 0.32) and slowest (CV = 0.72, LOA = 0.47) swimmers.

The Pearson moment correlation (Table III) was used to measure the strength of a linear association between variables. For freestyle, trial 1; there were significant values with strong relationships highlighted for split time (R = 0.99, P = 0.00), stroke rate (R = 0.91, P = 0.00), stroke count (R = 0.86, P = 0.00), and stroke index (R = 0.72, P = 0.00). All other variables are reported as not significant with weak relationships. For freestyle trial 2, there were significant values with strong relationships highlighted for split time (R = 0.99, P = 0.00), time underwater (R = 0.95, P = 0.00), stroke count (R = 0.86, P = 0.00). Speed was reported as significant (P = 0.02) with a weaker relationship (R = 0.50) than in trial 1 (R = 0.66). All other variables are reported as not significant with weak relationships.

For breaststroke trial 1, there were significant values with strong relationships highlighted for split time (R = 0.98, P = 0.00), stroke count (R = 0.87, P = 0.00) and speed (R = 0.90, P = 0.00). All other variables are reported as not significant with weak relationships. For breaststroke trial 2, there were significant values with strong relationships highlighted for split time (R = 0.99, *P* = 0.00), speed (R = 0.83, *P* = 0.00), stroke count (R = 0.79, *P* = 0.001), and stroke rate (R = 0.67, P = 0.004). All other variables are reported as not significant with weak relationships.

Paired-sample t-test calculations for comparison of the TritonWear® device against video analysis (validity) demonstrated no significant differences ($P > 0.05$) for freestyle in either trial, except for stroke index in trial 1 (T (9) = - 4.98, *P* = 0.00) and 2 (T (9) = - 3.74, *P* = 0.01), and time underwater (T (9) = 2.65, *P* = 0.027) for trial 2 only. Breaststroke validity data showed systematic bias for distance per stroke (T (9) = - 4.14, *P* = 0.003), turn time (T (9) = 2.31, *P* = 0.047) and stroke index (T (9) = - 3.74, P = 0.005) in trial 1, and distance per stroke (T (9) = - 4.94, *P* = 0.001), stroke rate (T (9) = 3.23, *P* = 0.01) and stroke index (T (9) = - 5.06, *P* = 0.00) in trial 2. Using the CV method, according to the arbitrary value of CV < 10 % (Stokes 1985), these same results were reported as reliable for key variables 'split time' and 'speed', during the validity analysis (CV = 0.95 % - 6.82 %).

Concurrent validity and reliability were assessed using a 95 % limits of agreement (Table IV) (Bland and Altman, 1986), coefficient of variation (Atkinson and Nevill, 1998). Data showed the best overall LOA correlations for freestyle were speed in trial 1 (0.21 %) and turn time (0.27 %) trial 2, and for breaststroke; speed in trial 1 (0.08 %) and speed in trial 2 (0.17 %). Coefficient of variation (Atkinson and Nevill, 1998) data was best correlated for freestyle for split time in trials 1 (1.06 %) and 2 (1.88 %), and breaststroke split time in trial 1 (0.95 %) and 2 (0.66 %).

Table I. Reliability of TritonWear data against video analysis data (n = 20).

Reliability Data	Trial 1 (mean ± s)	Trial 2 (mean ± s)	95% LOA	CV (%)
Triton freestyle:				
Split time (s)	17.45 ± 2.34	17.99 ± 2.41	-0.55 ± 0.94	1.91
Stroke count (n)	19.3 ± 1.77	19.3 ± 1.70	0.00 ± 1.85	3.46
Speed (m/s)	1.41 ± 0.19	1.38 ± 0.17	0.031 ± 0.07	1.84
Stroke rate (n/min)	1.49 ± 0.22	1.53 ± 0.17	-0.05 ± 0.14	3.45
Distance per stroke (m)	1.13 ± 0.29	1.10 ± 0.31	0.026 ± 0.13	4.36
Turn time (s)	1.12 ± 0.13	1.12 ± 1.12	0.006 ± 0.13	4.20
Time underwater (s)	2.72 ± 0.60	2.56 ± 0.67	0.16 ± 2.09	28.69
Stroke index	2.99 ± 0.55	2.87 ± 0.44	0.12 ± 0.57	7.03
Triton Breaststroke:				
Split time (s)	21.92 ± 2.22	22.08 ± 2.44	0.16 ± 1.20	1.98
Stroke count (n)	10.70 ± 2.06	10 ± 1.56	0.7 ± 2.45	8.58
Speed (m/s)	1.14 ± 0.14	1.11 ± 0.18	0.03 ± 0.22	7.16
Stroke rate (n/min)	1.56 ± 0.11	1.67 ± 0.14	0.12 ± 0.25	5.58
Distance per stroke (m)	1.51 ± 0.19	1.61 ± 0.30	0.10 ± 0.73	17.04
Turn time (s)	1.56 ± 0.11	1.43 ± 0.17	0.13 ± 0.37	8.97
Time underwater (s)	4.89 ± 2.06	4.14 ± 0.97	0.75 ± 3.85	30.90
Stroke index	1.74 ± 0.30	1.85 ± 0.49	-0.10 ± 0.95	19.10
Video Freestyle:				
Split time (s)	17.47 ± 2.44	18.10 ± 2.79	-0.63 ± 1.21	2.47
Stroke count (n)	19.30 ± 1.77	19.40 ± 2.17	-0.1 ± 1.45	2.70
Speed (m/s)	1.45 ± 0.17	1.41 ± 0.18	0.05 ± 0.08	2.03
Stroke rate (n/min)	0.78 ± 0.11	0.81 ± 0.11	-0.03 ± 0.08	3.50
Distance per stroke (m)	1.19 ± 0.10	1.18 ± 0.12	0.01 ± 0.08	2.51
Turn time (s)	1.13 ± 0.18	1.16 ± 0.14	-0.04 ± 0.17	5.27
Time underwater (s)	2.54 ± 0.28	2.51 ± 0.45	0.02 ± 0.49	6.99
Stroke index	3.48 ± 0.59	3.35 ± 0.62	0.13 ± 0.21	2.26
Video Breaststroke:				
Split time (s)	21.88 ± 2.23	21.95 ± 2.33	-0.07 ± 0.66	1.10
Stroke count (n)	10.80 ± 1.93	10.90 ± 1.73	-0.1 ± 1.72	5.72
Speed (m/s)	1.15 ± 0.11	1.15 ± 0.12	0.03 ± 0.04	1.11
Stroke rate (n/min)	0.61 ± 0.04	0.62 ± 0.05	-0.01 ± 0.06	3.46
Distance per stroke (m)	1.95 ± 0.27	1.92 ± 0.24	0.03 ± 0.22	4.11
Turn time (s)	1.36 ± 0.13	1.38 ± 0.12	-0.02 ± 0.10	2.68
Time underwater (s)	4.53 ± 0.89	4.68 ± 0.71	-0.15 ± 0.75	5.87
Stroke index	2.27 ± 0.51	2.68 ± 0.44	-0.41 ± 0.96	14.02

Note: LOA = 95% limits of agreement; CV = coefficient of variation. Significantly different ($P < 0.05$).

Table II. Paired sampled t-tests were used to calculate biases between the 'TritonWear' device and Video footage

	Trial 1 Sig. (2-tailed)	Trial 2 Sig. (2-tailed)	Trial 1 Sig. (2-tailed)	Trial 2 Sig. (2-tailed)
	Freestyle		Breaststroke	
Split time (s)	0.806	0.499	0.669	0.078
Stroke count (n)	1	0.726	0.678	0.726
Speed (m/s)	0.276	0.601	0.387	0.202
Stroke rate (n/min)	0.407	0.027	0.527	0.12
Distance per stroke (m)	0.414	0.333	0.003	0.001
Turn time (s)	0.192	0.325	0.058	0.01
Time underwater (s)	0.955	0.795	0.047	0.481
Stroke index	0.001	0.005	0.005	0.001

Table III. Pearson product-moment correlation was used to measure the strength of a linear association between variables

	Split Time	Stroke Count	Speed	Time Under water	Distance Per Stroke	Stroke Rate	Turn Time	Stroke Index
Validity Trial 1 Freestyle								
Pearson Correlation	0.995	0.929	0.812	-0.044	0.623	-0.953	0.48	0.85
Sig. (2-tailed)	0.00	0.00	0.004	0.905	0.054	0.00	0.16	0.002
R	0.99	0.86	0.66	0.002	0.39	0.91	0.23	0.72
Validity Trial 2 Freestyle								
Pearson Correlation	0.994	0.926	0.708	-0.973	0.674	0.435	0.524	0.757
Sig. (2-tailed)	0.00	0.00	0.022	0.00	0.033	0.208	0.12	0.011
R	0.99	0.86	0.50	0.95	0.45	0.19	0.27	0.57
Validity Trial 1 Breaststroke								
Pearson Correlation	0.991	0.934	0.949	0.577	-0.021	0.8	-0.018	0.481
Sig. (2-tailed)	0.00	0.00	0.00	0.081	0.954	0.005	0.961	0.159
R	0.98	0.87	0.90	0.33	0.0004	0.64	0.00	0.23
Validity Trial 2 Breaststroke								
Pearson Correlation	0.997	0.891	0.911	0.324	0.755	0.818	0.032	0.377
Sig. (2-tailed)	0.000	0.001	0.000	0.361	0.012	0.004	0.929	0.283
R	0.99	0.79	0.83	0.10	0.57	0.67	0.001	0.14

Table IV. Validity of TritonWear data against video analysis data (n = 20).

Validity Data	TritonWear (mean ± s)	Video (mean ± s)	95% LOA	CV (%)
Split time (s)				
Stroke count (n)	17.45 ± 2.34	17.47 ± 2.44	-0.021 ± 0.51	1.06
Speed (m/s)	19.3 ± 1.77	19.3 ± 1.77	0.00 ± 1.31	2.44
Stroke rate (n/min)	1.41 ± 0.19	1.45 ± 0.17	-0.041 ± 0.21	5.53
Distance per stroke (m)	1.49 ± 0.22	1.55 ± 0.21	-0.065 ± 0.13	3.01
Turn time (s)	1.13 ± 0.29	1.19 ± 0.10	-0.065 ± 0.47	14.64
Time underwater (s)	1.12 ± 0.13	1.13 ± 1.18	-0.003 ± 0.32	10.40
Stroke index	2.72 ± 0.60	2.54 ± 0.28	0.185 ± 1.32	18.15
Split time (s)	2.99 ± 0.55	3.48 ± 0.59	-0.49 ± 0.61	6.85
Breaststroke Trial 1				
Split time (s)	21.92 ± 2.22	21.88 ± 2.23	0.041 ± 0.57	0.95
Stroke count (n)	10.70 ± 2.06	10.8 ± 1.93	-0.1 ± 1.45	4.86
Speed (m/s)	1.14 ± 0.14	1.15 ± 0.11	-0.01 ± 0.08	2.79
Stroke rate (n/min)	1.56 ± 0.11	1.62 ± 0.14	-0.06 ± 0.17	3.77
Distance per stroke (m)	1.51 ± 0.19	1.95 ± 0.27	-0.44 ± 0.66	13.74
Turn time (s)	1.56 ± 0.23	1.36 ± 0.13	0.19 ± 0.52	12.91
Time underwater (s)	4.89 ± 2.06	4.53 ± 0.89	0.36 ± 3.35	25.76
Stroke index	1.74 ± 0.30	1.74 ± 0.29	0.005 ± 0.97	20.10
Freestyle Trial 2				
Split time (s)	18.00 ± 2.44	18.10 ± 2.79	-0.11 ± 0.94	1.88
Stroke count (n)	19.3 ± 1.77	19.4 ± 2.17	-0.1 ± 1.72	3.21
Speed (m/s)	1.38 ± 0.17	1.41 ± 0.18	-0.02 ± 0.26	6.82
Stroke rate (n/min)	1.53 ± 0.17	1.26 ± 0.16	0.27 ± 0.63	16.38
Distance per stroke (m)	1.10 ± 0.10	1.18 ± 0.12	-0.08 ± 0.49	15.51
Turn time (s)	1.12 ± 0.11	1.16 ± 0.14	-0.05 ± 0.27	8.51
Time underwater (s)	2.56 ± 0.67	2.51 ± 0.45	0.05 ± 1.14	16.20
Stroke index	2.87 ± 0.44	3.35 ± 0.62	-0.48 ± 0.80	9.33
Breaststroke Trial 2				
Split time (s)	22.08 ± 2.44	21.95 ± 2.33	0.13 ± 0.40	0.66
Stroke count (n)	10.80 ± 1.93	10.90 ± 1.73	-0.1 ± 1.72	5.72
Speed (m/s)	1.11 ± 0.18	1.15 ± 0.12	-0.04 ± 0.17	5.47
Stroke rate (n/min)	1.67 ± 0.17	1.59 ± 0.13	0.08 ± 0.16	3.58
Distance per stroke (m)	1.61 ± 0.30	1.92 ± 0.24	-0.31 ± 0.39	7.94
Turn time (s)	1.43 ± 0.17	1.38 ± 0.12	0.05 ± 0.40	10.42
Time underwater (s)	4.14 ± 0.97	4.68 ± 0.71	-0.54 ± 1.96	16.09
Stroke index	1.85 ± 0.49	2.68 ± 0.44	-0.84 ± 1.02	16.37

Note: LOA = 95% limits of agreement; CV = coefficient of variation. Significantly different ($P < 0.05$).

Discussion

The present study aimed to evaluate the reliability of the TritonWear® device for the variables that have been discussed. Based on the extrapolation of measurement error, and in accordance with the analytical goals set for this population of young athletes; the present study showed that the TritonWear® device is reliable for the measurement of split time, turn time and speed for high level junior swimmers. Additionally, data showed that variations in performance tend to decrease as swimming ability improves. The data suggests that for the key performance indicator of split time; so long as freestyle and breaststroke athletes using the device improve upon their initial trial by > 0.39 and > 1.05 seconds respectively, coaches can be confident that improvement has indeed been made. The data presented also suggests that for coaches seeking to improve turn times, it would be beneficial to test athletes over a period long enough to improve by 0.14 seconds and 0.5 seconds for freestyle and breaststroke respectively.

An analytical goal was set for split time to estimate the implications of the results on the sample population. Data shows that the average yearly improvement for the freestyle group was 3.1% or 2.09 s over 12 months, it's noted that this improvement is greater than the highest measurement error from reliability (0.39 s) and validity data (0.83 s). For breaststroke, the average yearly improvement (3.97 % or 3.32 s) was also greater than the highest measurement error from reliability (1.05 s) and validity (0.62 s) data. Therefore, to ensure that performance improvements were not due to measurement error of the instrument, based on the data presented; a freestyle athlete would need to improve by at least 0.39 s, and a breaststroke athlete by at least 1.05 s when using the TritonWear® device, and 0.58 s and 0.6 s respectively when using video analysis. It's worth considering that these improvements occurred over a period of 12 months. For coaches utilising this technology with youth athletes, based on the data provided; it is advised that sufficient time between testing sessions is allotted to allow for sufficient physiological improvement, including enhanced skill acquisition.

Additionally, through the analyses of reliability data of the device, as well as video footage; this study aimed to add some clarification to the notion that video analysis is itself a reliable method of quantitatively processing data that is useful to young swimmers. Realistically, physiological performance testing will not always occur over this time-frame. An interesting observation from the data is that freestyle 'split time' video analysis was 0.56 % (2.47 % – 1.91 %) more erroneous than the TritonWear® device over two trials, for freestyle 'speed' the video data was 0.19 % more erroneous (2.03 % - 1.84 %) than the TritonWear® device. The average agreement between the TritonWear® device and video (CV = 1.47 %) was 1 % higher than the agreement between the two video analyses (2.47 %), which can be seen by comparing validity and reliability data. Therefore, in relation to the analytical goals set out earlier, to feasibly assume that the athlete has made significant improvements in split times and speed for freestyle over 100 metres, that athlete would need to improve > 2.47 % and > 1.84 % respectively if the data is being analysed by video, and > 1.91 % and > 2.03 % respectively if the data is being analysed with the TritonWear® device. This difference can be entirely explained by the video analyses procedure, rather than by the athlete themselves, as the error grows in the video analysis despite testing identical trials, reasons for this finding could be a result of an accumulation of marginal errors in during the video analyses. The accuracy of the data collection marginally decreases as the velocity of swimming increases, possibly due to the minute differences in body segment positioning during key phases of the swim. Increased swimming velocity has also been linked to camera footage obscuration due to disruption such as water turbulence and bubbles (Payton, 2008) which is more likely to occur as swimmers are moving faster. An interesting finding, when you consider that video analysis is currently regarded as the gold standard in performance testing for swimming (Ceseracciu, Sawacha, Fantozzi, Cortesi, Gatta, Corazza & Cobelli, 2011). It's possible that the highly complex nature of technical video analyses, in addition to the technique variability of athletes between trials can result in unreliable interpretation of the video footage. Research suggests that there are several potential explanations to explain why video analyses might present such discrepancies. Kwoon and Casebolt (2010) suggest that image disturbance due to refraction is a common obstacle when performing underwater video analysis; specifically; calibration of the camera in the water, inadequate lighting underwater and bubbles created by the swimmer appear to be the key issues. In addition, the cameras used videoed at 30 progressive video frames per second, which suggests that to decrease the amount of associated error; the assessor might need to use camera equipment above 30 frames per second. In contrast, breaststroke data reported opposing trends; the TritonWear® device was 0.88 % more erroneous for split time recording (1.98 % - 1.10 %) than the video analysis, and for speed; breaststroke data was a substantial 6.05 % more erroneous (7.16 % - 1.11 %) than the video data. This suggests that when split times are slower; video analyses become more reliable. The average split time for freestyle across both trials and devices was 4.21 seconds faster than for breaststroke, and speeds 0.27 metres per second slower for breaststroke.

Regarding turn time, the data presented show that, similarly to split time and speed data, the TritonWear® device is more reliable than video analyses for freestyle, but less reliable for breaststroke. For freestyle 'turn time'; video analysis CV was 1.07 % (5.27 – 4.20) more erroneous than the TritonWear® device over the two trials, for breaststroke; CV data showed that video data was 6.29 % (CV = 8.97 % – 2.68 %) less erroneous than the TritonWear® device. These findings offer a possible explanation for the previously discussed error increases associated with video analysis for freestyle split time and speed; it is likely that the difficulties of analysing video footage for freestyle turns due to swimming velocity can alter the overall accuracy of the data collected for both split times and speed. Based on data from 95 % limits of agreement analysis; for an athlete using the TritonWear® device for freestyle, they must improve > 0.14 seconds between trials for a meaningful improvement to be calculated, any improvements below this number could be due to error of the instrument rather than improvement of the athlete. The mean difference between trial 1 and trial 2 of average turn times for freestyle was 0.006 seconds using the TritonWear® device, a number which exceeds that of the underestimation of the device. For breaststroke, an athlete must improve > 0.5 seconds between trials for a meaningful improvement to be calculated, the mean difference between trial 1 and trial 2 for average turn times with breaststroke was 0.13 seconds using the TritonWear® device. This data suggests that the TritonWear® device is more accurate at calculating freestyle turn times than it is for breaststroke when compared to video analysis. However, the associated underestimations from both video analysis and the TritonWear® device were greater than that of the average difference of athletes between two trials. A suggestion could be made that for coaches seeking to improve turn time, a longer period of time should be planned between testing sessions to allow the athlete to make sufficient turn-time improvements; > 0.14 seconds for freestyle and > 0.5 seconds for breaststroke when using the TritonWear® device.

The key variables analysed show strong correlations between the device and the video footage, potentially due to the data comparisons being made concurrently within one swim. Inter-trial reliability testing highlighted an increase biological error, likely due to the high possibility that subjects will differ in two trials on different days. Breaststroke split time reliability data varied 1.18 %, when average validity (CV = 0.80 %) is subtracted from reliability (1.98 %), freestyle reliability data showed similar correlations, where reliability data differed 0.44% (1.91 % -

1.47 %). The recorded error for breaststroke increased nearly 1.5 times by allowing the athlete to swim on separate occasions, suggesting that inter-trial testing allows subjects to have an influence over the result of their performance that is effecting the error recorded by the devices. Interestingly, each breaststroke variable (except turn time), reported a CV higher in the TritonWear® reliability data than the average of both validity trials (1.79% average difference), further adding to the likelihood that by completing trials on different days is likely to result in some degree of variance in performance, the data presented suggests that this variance is most likely due to individual biological differences. The systematic bias highlighted using a paired samples t-test shows that for both the TritonWear® data, and video data; that the freestyle group were on average slower in the second trial than in the first. One assumption to explain the abnormal data distribution is that the second trial took place at the end of a training week. It is possible that, despite trying to minimise the likelihood of athletes becoming fatigued between trials; that this group of ten swimmers were slower due to the accumulation of training over the course of the previous 4 days.

The coefficient of variation in performance between trials is a key statistic to measure for a coach who is interested in implementing methods that might positively affect performance. Hopkins, Hawley, & Burke (1999) claim that to improve an athlete's chances of winning a medal, strategies need to be adopted that will improve an athlete's performance by an amount that is equivalent or higher than 0.5 of the coefficient of variation. Stewart and Hopkins (2000) noted that the variation between competitive trials for 311 national-level junior athletes was approximately 1 %, meaning that improvements in trial times for each of these athletes would need to equal just 0.5 %. The lowest TritonWear CV data for split times was 1.91 for freestyle, a coach using this data would look to key skills such as turn time to determine where this athlete might be able to make improvements equal or above 0.95 %. As previously mentioned, turn time, including time underwater, could make up approximately 20 % of the total race Thayer and Hay (1984). It would therefore be advisable, based on the literature, for the coach to seek an improvement in turn time by 5 % to raise overall time by 0.95 %. As previously discussed, to account for error of the TritonWear® device for freestyle turn time, an athlete would need to improve by 0.14 seconds + 5 % of their previous turn time (mean 1.12 seconds). Using data in the current study, the coach could seek to improve overall performance by 0.95 % by improving turn time by 0.196 seconds (5 % of 1.12 + 0.14 seconds) and time underwater by 2.77 seconds (average time underwater + 5 %) over the course of the entire race. However, for time underwater; consideration needs to be given to the possibility that there is a 2.25 second potential error associated with that metric as shown through the 95% LOA method. This process is one example of the advantages that immediate and reliable feedback can provide coaches working with junior swimmers.

One of the aims of the present study was to determine how ability level of the athlete changes usefulness of the device. Stewart and Hopkins (2000), studied between-competition variation in performance for 149 males and 162 female junior athletes, swimming at a national level. They reported that faster swimmers (CV = 1.1%, 95 % CL = 0.8 - 1.5%) showed greater consistency in performances between competitions than slower swimmers (CV = 1.55 %, 95 % CL = 1.2-2.2 %). The data presented in this study is comparable; findings suggest that on average, as swimming ability improves, individual variation between trials decreases. More able swimmers can select a pace that is closer to their optimum, and are more competent in the highly technical skills such as turn time and time underwater. When using this device, it is important that the coach considers the likelihood that the data provided for the less able swimmers will have higher inaccuracies. It is highly likely that athletes who are still learning will demonstrate higher levels of technique variability in their performances, especially when margins for error are so small.

Conclusion

Based on the evidence provided, it is suggested that the TritonWear® device can be used to reliably measure the swimming performance variables of split time, speed and turn time in training and competition of high level junior swimmers. Coaches who opt to use video footage to analyse swimming performance should be cautious when attempting to measure complex skills at high velocities such as freestyle turns. In addition, future analysis of youth swimming performance should take measures to minimise systematic bias by limiting the effects of training fatigue on participants. Based on the current findings, the present study shows that the TritonWear® device is reliable for the measurement of split time, turn time and speed for high level junior swimmers. Finally, based on the framework presented by Batterham and Atkinson (2005), future research using the data provided should use a sample size of > 20 participants should be used to make meaningful inferences for the variables split time, speed and turn time.

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Appendices

Ethics Approval Letter

St Mary's University Twickenham London

28 February 2017 Unique Ref: SMEC_2016-17_050

James Butterfield (SHAS): 'Concurrent validity and test-retest reliability of an elite tracking system to assess eight swimming performance variables'

Dear James

University Ethics Sub-Committee

Thank you for submitting your ethics application for the above research.

I can confirm that your application has been considered by the Ethics Sub-Committee and that ethical approval is granted.

Yours sincerely

Prof Conor Gissane
Chair of the Ethics Sub-Committee

Cc Dr Mark Waldron

St Mary's Ethics Application Checklist

The checklist below will help you to ensure that all the supporting documents are submitted with your ethics application form. The supporting documents are necessary for the Ethics Sub-Committee to be able to review and approve your application.

Please note, if the appropriate documents are not submitted with the application form then the application will be returned directly to the applicant and may need to be re-submitted at a later date.

	Enclosed? (delete as appropriate)		Version No
Document	Yes	Not applicable	
1. Application Form	Mandatory		
2. Risk Assessment Form	Yes		
3. Participant Invitation Letter	Yes		
4. Participant Information Sheet	Mandatory		
5. Participant Consent Form	Mandatory		
6. Parental Consent Form	Yes		
7. Participant Recruitment Material - e.g. copies of Posters, newspaper adverts, website, emails		n/a	
8. Letter from host organisation (granting permission to conduct the study on the premises)	Yes		
9. Research instrument, e.g. validated questionnaire, survey, interview schedule		n/a	
10. DBS **(to be sent separately)**	Yes		
11. Other Research Ethics Committee application (e.g. NHS REC form)		n/a	
12. Certificates of training (required if storing human tissue)		n/a	

I can confirm that all relevant documents are included in order of the list and in one PDF document (any DBS check to be sent separately) named in the following format: ***Full Name, School, Supervisor.***

Signature of Applicant:

Signature of Supervisor:

ISB Varsity Swimming Team
Research Information Sheet

This aim of this document is to provide you with some important information on some research that has been planned for the ISB Varsity Swimming team, in which you have an invitation to participate in.
If you have any questions, please contact me at 145243@live.stmarys.ac.uk.

WHAT IS THE RESEARCH AND WHY IS IT BEING DONE?

As many of you know, assessment of swimming performance is becoming increasingly popular within high performance training centres such as ours. The 'TritonWear' technology that we currently use claims to accurately measure a range of performance variables, including; speed, split time, turn time, time underwater, stroke count, stroke rate, distance per stroke, and stroke index. The aim of this research is to test the reliability and validity of this device so that we can estimate how useful the data is to us. This study has been planned by James Butterfield who is studying his masters in Strength and Conditioning from St Mary's University, Twickenham (London TW1 4SX).

There are a few reasons why the results of this study may be useful to you as a member of the varsity swim team. Firstly, many of you are already using 'TritonWear' device weekly in your training with the aim of enhancing performance, through knowledge and understanding of the information that the device gives you. In order to know how much we can use this data, we first need to have an understanding of it's reliability to be confident that the data is correct. We also want to see if the information the device gives us is valid, we can do this by measuring the data against video analysis. The research hopes to provide you with information on the extent to which this data can be used to enhance your performance. In addition, the research will be beneficial to the swimming department, who have spent a substantial amount of money on this technology.

WHAT IS THE TITLE OF THE STUDY?

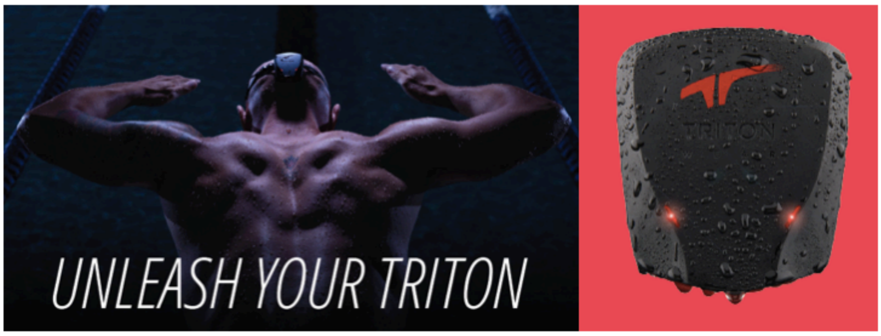
Concurrent validity and test-retest reliability of an elite tracking system to assess eight swimming performance variables.

WHAT WILL I BE ASKED TO DO AND IS IT RISKY?
In January, swimmers will be asked to complete two 100 metre swims (4 x 25m) at race pace for either front crawl or breast stroke. The two swims - which will happen on different days - will then be compared to see how reliable the device is. The data will also be compared to video analysis in order to measure it's validity. This study isn't risky and will not require you to do anything that you are not already doing in daily swimming practice.

WHAT IF I DON'T WANT TO PARTICIPATE?
Then you don't have to…there is absolutely no pressure for you to take part in this research. If you start to take part and change your mind half-way through, just let me know and we can cancel your participation right away.

WILL MY SCORES BE PUBLICLY AVAILABLE?
Yes, however your name will not be attached to your scores as data will be presented as a group average. Therefore nobody will know it was you who provided that piece of data. In addition, all data will be fully protected and will remain confidential.

WHAT DO I DO NOW?
You don't need to do anything right now. Soon we will ask if you are happy to participate in the research and you can make an informed decision based on the information above.



St Mary's University Twickenham London

ISB Varsity Swimming Team
Participant Consent Form

NAME:

………

TITLE OF THE PROJECT:
Concurrent validity and test-retest reliability of an elite tracking system to assess eight swimming performance variables

JAMES' CONTACT DETAILS:
Email - 145243@live.stmarys.ac.uk
Phone - 0943385236

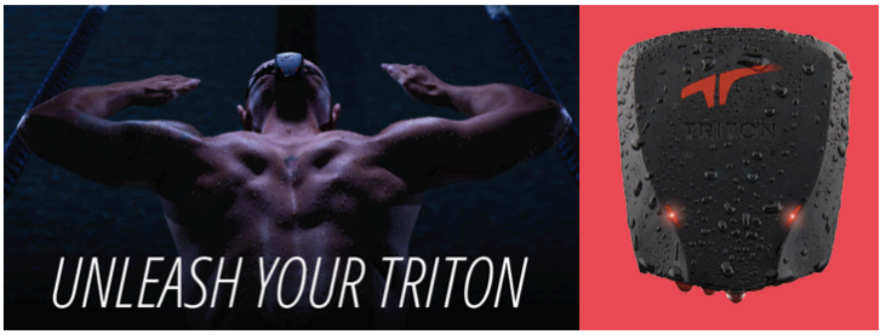
IMPORTANT INFORMATION:

1. I agree to take part in the above research. I have read the participant information sheet and I understand what my role will be in this study.
2. All my questions have been answered and I am satisfied with the information given to me
3. I understand that I do not have to take part in this research and that I can withdraw at any time and for any reason.
4. I am happy that my personal information will remain confidential and that the data collected will be safeguarded.
5. I know that I can ask any questions at anytime, using the contact information above.
6. I have been provided with a copy of this form as well as the information sheet.
7. I agree that St Mary's University can process the personal data that I and my parent / guardian has supplied. I agree to the processing of this data for any purposes connected with the Research Project as outlined to me.

NAME: ……………………………………………………………………………………………………

STUDENT NUMBER: …………………………

SIGNATURE: …………………………………..



St Mary's
University
Twickenham
London

ISB Varsity Swimming Team
Parent / Guardian Consent Form

St Mary's University Twickenham London

CHILD'S NAME:

……………………………………………………………………………………………………….

TITLE OF THE PROJECT:
Concurrent validity and test-retest reliability of an elite tracking system to assess eight swimming performance variables

CONTACT DETAILS:
Email: 145243@live.stmarys.ac.uk Phone - 0943385236
University Website: http://www.stmarys.ac.uk/
University Phone: +44 (0) 20 8240 4000
University Address: St Mary's University, Waldegrave Road, Strawberry Hill, Twickenham, TW1 4SX

1. I agree to my child taking part in the above research. I have read the Participation Information Sheet which is attached to this form. I understand what my child's role will be in this research, and all of my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw my child from the research at any time, for ant reason and without prejudice.
3. I have been informed that the confidentiality of the information I and my child provides will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.

Data Protection: I agree to the University processing personal data which I and my child have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

PARENT/GUARDIAN NAME: …………………………

SIGNATURE: ………………………………….

DATE: ……………………………………….

If you wish to withdraw your child from the research, please complete the form below and return to James.

Title of Project: Concurrent validity and test-retest reliability of an elite tracking system to assess eight swimming performance variables.

I WISH TO WITHDRAW MY CHILD FROM THIS STUDY

Name of Participant: …………………………..

Name of Parent:…………………………..

Signed:………………………….. Date:…………………………..