THE VALIDATION OF A SWIMMING TURN WALL-CONTACT-TIME MEASUREMENT SYSTEM

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The effectiveness of the swimming turn is highly influential to overall performance in competitive swimming. The push-off or wall contact, within the turn phase, is directly involved in determining the speed the swimmer leaves the wall. Therefore, it is paramount to develop reliable methods to measure the wall-contact-time during the turn phase for training and research purposes. The aim of this study was to determine the reliability and concurrent validity of the *Pool Pad* system to measure wall-contact-time during the turn. Despite measurement differences, the results analyses demonstrated that the *Pool Pad* is suitable for measuring wall-contact-time within a training environment.

KEY WORDS: tumble turn, open turn, reliability, concurrent validity, and feedback.

INTRODUCTION: Successful performance in competitive swimming events relies heavily on the effectiveness of the swimming turn, especially for the longer races (Chakravorti, Slawson, Cossor, Conway, & West, 2012; Slawson, Conway, Justham, Le Sage, & West, 2010; Webster, West, Conway, & Cain, 2011). The swimming turn involves the approach to the wall, the turn or rotation to reorient the body in preparation for swimming the next lap, the push-off or wall contact, the glide phase and the stroke preparation (Cossor, Blanksby, & Elliott, 1999; Slawson et al., 2010; Webster et al., 2011). To optimise the turn, the swimmer must keep this sequence to the shortest time possible while achieving the highest possible speed in the opposite direction (Slawson et al., 2010; Tourny-Chollet, Chollet, Hogie, & Papparodopoulos, 2002; Veiga, Cala, Frutos, & Navarro, 2013; Webster, West et al., 2011).
The push-off the wall has been identified to be directly involved in determining the speed at which the swimmer leaves the wall (impulse-momentum relationship) (Hay, 1993). In short, the larger the impulse (average force applied to the wall for a given time) the greater the speed (velocity) the swimmer will travel away from the wall (Araujo, et al., 2010). Thus, with the identified importance of the wall-contact-time within the swimming turn, coaches were looking for new technologies to measure this wall-contact-time and provided real-time feedback to their athletes.
Recent research on feedback in sport has indicated that there has been a large shift towards real-time feedback during training. In addition, feedback needs to be considered from both a measurement and a relevance perspective while being task and performer specific (Phillips et al., 2013). Currently, there are no low-cost timing systems commercially available to provide real-time tumble and open turn feedback to athletes and coaches. This led to the development of the *Pool Pad* (Superinteractive, Geelong, Australia) Application (App). The *Pool Pad* system connects directly in to the Omega OCP5 touchpad currently used at major swimming pools and competitions. Thus, the purpose of this pilot study was to determine if this *Pool Pad* system is suitable and reliable to measure wall-contact-time accurately for all swimming turn techniques within a swimming training environment.

METHODS: Nine elite and sub-elite swimmers performed the tumble turn trials and four elite and sub-elite swimmers performed the open turn trials. The *Pool Pad* App (displayed on an Apple iOS device) connected to the Omega OCP5 touchpad (with a sampling rate of 250 Hz) via the Superinteractive Stomp Pad USB MIDI cabling system. Time-validated video from an iPhone 6s (iOS 9.3.5, Apple Inc., California, USA) was used as the criterion measurement as video analysis is standard and widespread in swimming (Slawson et al., 2010).The iPhone 6s camera recorded using slow-motion video support operating at 240 frames-per-second (fps). Ammann (2016) also stated that from previous research on measuring ground contact time, video techniques were recommended.

For the tumble turn, either freestyle or backstroke was swum and for the open turn, either breaststroke or butterfly. All athletes swam towards the Omega OCP5 touchpad where he/she completed the tumble or open turn and then would glide / recover back to the 15 m mark or continue swimming according to their training regime. Four separate Omega OCP5 touchpads were used within the turn trials. The same Omega OCP5 touchpad was used for the four swimmers which performed the open turn trials (athlete J to M). This same Omega OCP5 touchpad was also used for eight of the nine athletes (athletes B to I) which performed the tumble turn trials where athlete A used a different Omega OCP5 touchpad over three separate training sessions. The use of multiple touchpad was used as the study was designed to test swimmers during their regular training sessions and also gave a true reflection of the *Pool Pad*'s reliability which was explored through the statistical analyses.

Reliability and concurrent validity statistical analyses were undertaken using two customised Microsoft Excel 2013 spreadsheets created by Hopkins (2015). Reliability statistics included intraclass correlating coefficient (ICC) while the standardised typical error estimate, linear analysis and effect size were used for the concurrent validity statistics. These spreadsheets provided simple linear regression analysis, in which the criterion was the dependent variable and the practical was the predictor. An additional concurrent validity analysis was performed to assess the Pool Pad's response to different Omega OCP5 touchpads using the same athlete (athlete A).

RESULTS: A total of 74 tumble turn trials and 37 open turn trials were assessed using a single Omega OCP5 touchpad. The R^2 value for the tumble turn and open turn trials was 0.80 and 0.93, respectively. Following the reliability statistical analyses, the ICC value from the tumble and open turn trials resulted in a value of 0.89 and 0.97, respectively. Pearson's correlation, typical error of estimate, Bland and Altman Estimate and the overall bias were generated from the validity spreadsheet (refer to Table 1). The mean wall-contact-times from the *Pool Pad* system and the time-validated video (criterion) per individual athlete, following the statistical standardisation and removal of univariate and bivariate outliers, are displayed in Table 2 including the R^2 value and Person's Correlation.

Table 1
Concurrent Validity Results using Single Omega OCP5 Touchpad

	Tumble Turns B to I	**Open Turns J to M**
	Estimate (s)	Estimate(s)
Overall Bias		
Mean bias in raw units	0.01	0.00
Mean bias standardised	0.25	0.04
SD of bias in raw units	0.03	0.03
SD of bias standardised	0.49	0.26
Typical Error of Estimate		
Raw units	0.02	0.03
Standardised	0.45	0.25
Person's Correlation		
	0.89	0.97
Bland-Altman		
± 95% Limits of Agreement	0.05	0.05

Table 2

Individual Athlete Trial Mean Values and Statistical Analysis Results

Athlete ID	No. Turns	*Pool Pad* (s)	Video (s)	R^2	Person's Correlation
A_1	19	0.44 ± 0.05	0.37 ± 0.03	0.65	0.48
A_2	12	0.55 ± 0.05	0.35 ± 0.02	0.04	0.19
A_3	22	0.39 ± 0.04	0.32 ± 0.03	0.66	0.81
B	10	0.27 ± 0.02	0.26 ± 0.02	0.85	0.92
C	9	0.24 ± 0.02	0.23 ± 0.02	0.68	0.70
D	8	0.33 ± 0.03	0.33 ± 0.03	0.94	0.97
E	10	0.39 ± 0.04	0.37 ± 0.04	0.68	0.82
F	10	0.27± 0.03	0.26 ± 0.02	0.59	0.77
G	8	0.27 ± 0.01	0.26 ± 0.01	0.98	0.99
H	10	0.32 ± 0.04	0.27 ± 0.03	0.78	0.88
I	9	0.30 ± 0.06	0.32 ± 0.05	0.83	0.91
J	8	1.27 ± 0.04	1.26 ± 0.03	0.53	0.73
K	10	1.31 ± 0.03	1.31 ±0.04	0.26	0.51
L	10	1.28 ± 0.04	1.26 ± 0.03	0.75	0.87
M	9	1.05 ± 0.02	1.06 ± 0.03	0.27	0.52

DISCUSSION: The reliability of the *Pool Pad* was calculated to determine its consistency and reproducibility to measuring wall-contact-time (Atkinson & Nevill, 1998; Hopkins, 2015). This analysis was performed using the wall-contact-times from the same Omega OCP5 touchpad from eight of the nine trialled swimmers (athletes B to I), for the tumble turn, and all four trialled swimmers (athlete J to M) for the open turn. Athlete A was removed for this reliability analysis as using different Omega OCP5 touchpads may have affected the overall true reproducibility of the *Pool Pad* system's wall-contact-time measurement. Following the removal of univariate and bivariate outliers, the overall ICC between the *Pool Pad* system (practical) and the time-validated video (criterion), for the tumble turn trials, was very strong (ICC = 0.89 with limits of agreement = 95% n = 74). Similarly, for the open turn athlete trials, the relationship between the *Pool Pad* system and time-validate video was also very strong (ICC = 0.97 with limits of agreement = 95%, n = 37). This indicated that the *Pool Pad* system was suitable for practical application over a range of athletes when the same Omega OCP5 touchpad was used.

Concurrent validity analysis was assessed to ensure the *Pool Pad* system's ability to measure wall-contact time accurately. The regression equation returned an R^2 value of 0.80 and 0.93 for the tumble and open turn, respectively, which was interpreted as a very high correlation according to Hopkins (2015). Nevertheless, assessing the individual athlete trial sets illustrated a low R^2 value for athlete K and M indicating a weak relationship between the time-validated video footage and the *Pool Pad* system. These two athletes were considered sub elite and hence their performance was more variable compared to the elite subjects' trialled. Additionally, despite the small sample size, these discrepancies did not affect the overall validity of the of Pool Pad system. Also, for both the tumble and open turn, the standardised typical error estimate of 0.45 and 0.25 was interpreted as small and moderate, respectively. This indicated that the differences between the time-validated video and the *Pool Pad* system would have a small practical significance to the wall-contact-time measurement displayed on the *Pool Pad* App (Hopkins, 2015). With these concurrent validity results, the coaches could be confident that the wall-contact-times displayed on the *Pool Pad* App are accurate for that particular Omega OCP5 touchpad.

Assessing the concurrent validity using the same subject over multiple Omega OCP5 provided an additional layer of analysis. The R^2 value of 0.04 for the athlete A_2 trial set illustrated a close to zero relationship between the time-validated video footage and the *Pool Pad* system. Therefore, a potential explanation was directed at the sensors within the Omega OCP5 touchpad as the *Pool Pad* system connects directly into this hardware and relies heavily on its integrity. The longer wall-contact-time measurements recorded by the *Pool Pad* system for A_2 could have been caused by issues with the sensors within the Omega OCP5 touchpad ceasing to function as a switch and acting as a battery. This would result in the sensors storing voltage, meaning that at the instant that the foot leaves the Omega OCP5 touchpad the signal may take a short period of time to return to the zero datum. Larger differences between the time-validated video and the *Pool Pad* system for A_1 and A_3 could also be potentially due to the accuracy of the Omega OCP5 touchpad. Athlete A_3 trial set illustrated the most consistent wall-contact-times across the 22 turn trials resulting in an R^2 value of 0.66 and the standardised typical error estimate of 0.60. This indicated that the difference between the time-validated video and the *Pool Pad* system would have a moderate practical significance (Hopkins, 2015). These measurement differences across the three separate training sessions gave the athletes and coaches an awareness of the measurement uncertainty between varying Omega OCP5 touchpads. As a consequence of this it has been recommended to Superinteractive that the Stomp interface cable and algorithm within the *Pool Pad* App be modified to account for these uncertainties within varying Omega OCP5 touchpads. Furthermore, a customised touchpad has since been developed which has alleviated uncertainties found from using the Omega OCP5 touchpads.

CONCLUSION:

This study aimed to examine pre-existing tumble and open turn wall-contact-time data measured from the *Pool Pad* App. The results from the reliability and concurrent validity analyses indicated that the system is suitable for practical application using one particular Omega OCP5 touchpad. The statistical results from the individual athlete, which used a different Omega OCP5 touchpad across the three training sessions, presented findings which further indicated that the *Pool Pad* system is dependent on the adequate functionality of the sensors within the Omega OCP5 touchpad. This dependence is due to the *Pool Pad* system's direct connection into the Omega OCP5 touchpad and thus, it relies on its integrity.

These findings gives coaches and athletes confidence in the reproducibility of the *Pool Pad* system to measure wall-contact-time within the training environment (providing the adequate functionality of the Omega OCP5 touchpad) and can lead to future research and development opportunities.

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