HOW CRITICAL IS THE CHOICE OF DISTANCE-BASED MEASURES IN STUDYING TUMBLE TURN PERFORMANCE?

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The turn is a crucial part of swim races and therefore requires systematic investigation. Yet, many different measures of turn performance are used in the literature. This study aimed to examine the level of agreement and the sensitivity of six fixed-distance based performance measures of the tumble turn. Tumble turn data of 10 Dutch elite level swimmers were analysed using those measures. The overall level of agreement was high between all measures (R ranging from 0.91 to 0.99). However, if the swimmers were ranked according to each of those measures, not all performance measures resulted in the same ranking. In particular, the rankings for measures with an exist distance of 10 m deviated from those for measures with an exit distance of 5 or 15 m. This finding suggests that the performance measures of interest are sensitive to different phases of the turn.

KEYWORDS: swimming, level of agreement, sensitivity.

INTRODUCTION: Turning is an important part of competitive swimming, which determines a considerable portion of the overall swim performance. The freestyle tumble turn consists of five phases: approach, rotation, push-off, underwater swimming and stroke resumption. Research has shown that the accumulated duration of turns represents at least 19% of the total race time in long course races and up to 44% in short course races (Veiga et al., 2013; Morais et al., 2019a; Morais et al., 2019b; Born et al., 2021). Nonetheless, no consensus exists about which operational definition for measuring the time associated with turning captures turning performance best. In pertinent literature two types of definition for turning performance are found, one based on fixed differences and the other based on variable distances depending on action events. In the first type of definition, turn performance is defined as the time that elapses between the swimmer passing a fixed distance from the wall when approaching it and passing a fixed distance from the wall when moving away from it. In the second definition, turn performance is defined as the time that elapses between the submergence of the head at turn initiation and the resurface of the head after the turn. Within the first type of definition, there is quite some variation in the literature regarding the reference distances that are chosen to measure turn performance. As a consequence, it is difficult to compare results across studies. Silviera et al. (2011) proposed that the 5 m round time provides the best measure to describe turning performance for sub-elite swimmers, because this measure contained all turn related actions and had the lowest percentage of free-swimming time. To our knowledge, no other attempts than this have been made to standardize the measurement of turn performance. Instead of searching for the best suitable performance measure, which may be hard to establish in an absolute sense, it may be useful to examine the level of agreement between different turn performance measures. After all, the higher this agreement, the less critical the choice of performance measure. The aim of this study was therefore to examine the sensitivity of the turn performance measures commonly used in the literature. This was done purposefully in a sample of elite swimmers because they exhibit consistently high turning performances and comparatively little variability.

METHODS: For this study extensive retrospective front crawl turn data from 10 elite swimmers, 4 male swimmers (age: 24.5 ± 1.7 years and FINA points: 891 ± 22) and 6 female swimmers (age: 27.5 ± 4.9 years and FINA points: 914 ± 63), were analysed (mean ± standard deviation).

The turn data were collected over a period of 11 years (from 2010 until 2021).The FINA points assigned to each participant were based on their personal best performances on a freestyle race event (50, 100 or 200 m). All turn data were recorded by a video system consisting of 4 cameras (scA1400-30gc, 50 Hz, Basler, Ahrensburg, Germany), which were built into the pool's side wall (2 m, 5 m, 10 m, and 15 m from the wall) at a depth of 0.55 m. During the recordings the swimmers began swimming about 15 m before the wall, sprinted towards the wall, made their turn and sprinted back until they were well beyond the 15 m mark. All trials were recorded during training sessions and performed at maximal effort.

All videos were analysed manually using custom-made software, which translated all pixels in the field of view of the cameras to 2D coordinates on the midsagittal plane of the recording lane by applying the direct linear translation (Abdel-Aziz, Kararam, & Hauck, 2015). The resulting data were stored in a database. All turn data of the 10 elite swimmers were extracted from the database and filtered for trials that contained the times at which the trochanter passed the 5 m and 3 m mark before contacting the wall and the 5 m, 10 m and 15 m mark after contacting the wall. Based on these times the following performance measures were determined for each turn: 5 m in to 5 m out, 3 m in to 5 m out, 3 m in to 10 m out, 5 m in to 10 m out, 3 m in to 15 m out and 5 m in to 15 m out.

Subsequently, repeated measures correlation coefficients (Bakdash & Marusich, 2017) were calculated for all possible pairs of these performance measures and collated in a correlation matrix. In addition, the swimmers were ranked for each performance measure to examine how strongly those rankings were affected by the choice of performance measure. The rank order was determined based on the average of the 10 fastest turns per participant for each measure. To determine where the turn was initiated and ended, the distance from the wall at which the head was completely submerged and the distance from the wall at which the head resurfaced are also given averaged per person and performance measure.

RESULTS: A total of 605 turn trials remained after filtering for the required data fields. Figure 1 shows the data distributions for all participants for the highest correlation and the lowest correlation, that is, the 5 m in – 5 m out vs the 5 m in – 15 m out and the 3 m in – 10 m out vs the 5 m in – 10 m out, respectively.

There were very strong ($R > 0.9$) positive significant correlations between all performance measures. The lowest correlation ($R = 0.909$) was found between the 3 m in – 5 m out and the 3 m in – 15 m out performance measures, while the highest correlation ($R = 0.991$) was found between the 3 m in – 10 m out and the 5 m in – 10 m out performance measures.

Table 1 shows the mean turn performances for the 10 fastest trials of the participants ranked for each performance measure. The turn was initiated at 1.91 ± 1.51 m from the wall and the swimmers resurfaced at 8.66 ± 0.89 m from the wall after the turn. The changes in rank order relative to the 5 m in – 5m out performance measure are highlighted in red; this measure was chosen as reference in view of the recommendation of Silviera et al. (2011). The fastest and slowest male and female swimmer were the same for all performance measures. Most changes in rank order occurred in the performance measures that used an exit distance of 10 m from the wall. The turn was initiated at 1.91 ± 1.51 before the wall and the swimmers resurfaced at 8.66 ± 0.89 m after the turn.

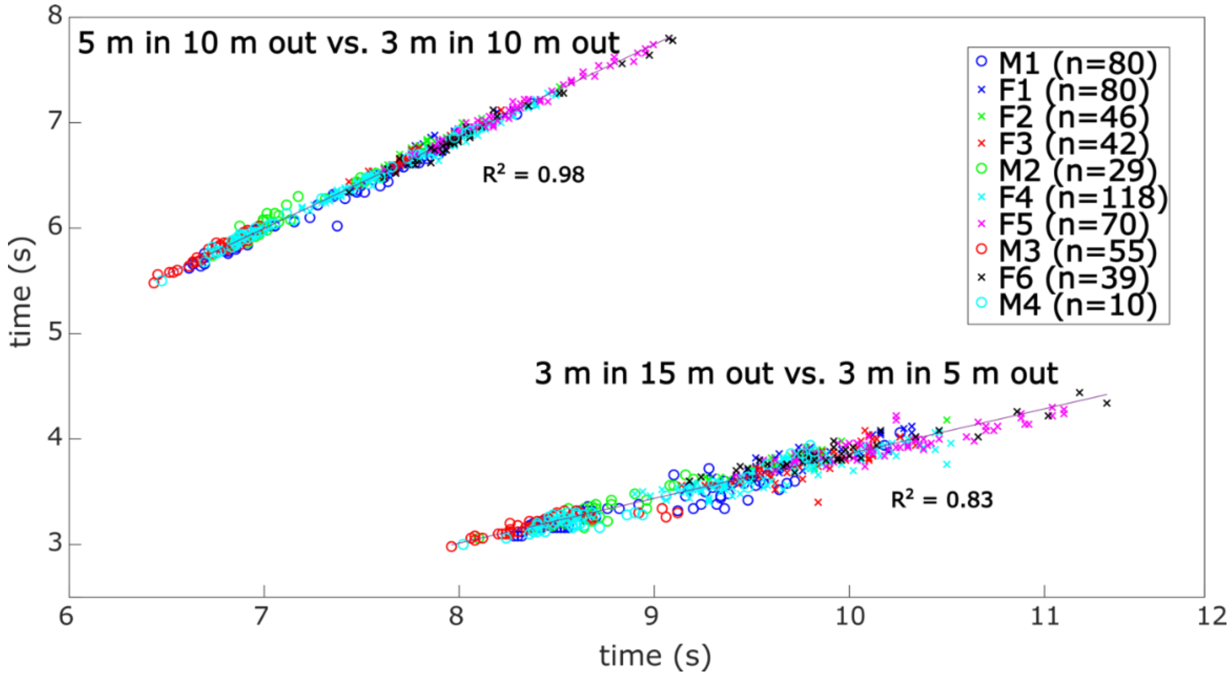

Figure 1: Distribution of data of the 5 m in - 10 m out vs 3 m in - 10 m out time and of the 3 m in - 15 m out vs 3 m in - 5 m out time. The R^2 values represent the explained variance for both correlations.

Table 1: The rank orders and times in seconds based on the 10 fastest trials of the participants ranked for each performance measure. All rank orders are compared to the 5 m in - 5 m out ranking. Deviations from the 5 m in – 5 m out ranking are highlighted in red.

	5m in - 5m out		3m in - 5m out		3m in - 10m out		5m in - 10m out		3m in - 15m out		5m in - 15m out	
	Rank	Time	Rank	Time	Rank	Time	Rank	Time	Rank	Time	Rank	Time
M3	1	4.03	1	3.07	1	5.62	1	6.58	1	8.15	1	9.11
M4	2	4.10	2	3.11	3	5.74	3	6.72	2	8.34	2	9.33
M1	3	4.13	3	3.13	2	5.71	2	6.72	3	8.36	3	9.35
M2	4	4.18	4	3.17	4	5.86	4	6.86	4	8.44	4	9.44
F4	5	4.50	5	3.45	5	6.23	5	7.29	5	9.07	5	10.11
F3	6	4.61	6	3.54	6	6.43	6	7.50	6	9.28	6	10.35
F2	7	4.74	8	3.68	9	6.59	8	7.65	8	9.44	7	10.51
F1	8	4.74	7	3.65	7	6.54	7	7.63	7	9.43	8	10.51
F6	9	4.83	9	3.70	8	6.57	9	7.70	9	9.47	9	10.60
F5	10	4.84	10	3.74	10	6.70	10	7.80	10	9.64	10	10.74

DISCUSSION: The aim of the present study was to examine the sensitivity of the measures for tumble turn performance used in the literature. To this end, routinely recorded turn trials of 10 Dutch elite level swimmers were analysed using six fixed distance-based performance measures. Based on the thus obtained turn times, the degree of agreement between those turn performance measures was assessed by calculating the repeated measures correlation coefficients for all possible pairs of performance measures. Even though the turn data had a marked unbalances in the number of turns per participant, the repeated measures correlation coefficient can accommodate unbalanced designs. This analysis revealed a high overall level of agreement with correlation coefficients ranging from 0.91 to 0.99.

However, when ranking the participants according to the different performance measures, it turned out that measures with an exit distance of 10 m showed marked changes (highlighted in red in table 1) in the ranking of the swimmers in comparison to measures with an exit distance of 5 m or 15 m. These changes in rank order coincided with the 5 m area where the swimmers resurfaced and continued free swimming, since the swimmers resurfaced at an average distance of 8.66 ± 0.89 m. The performance measures with an exit distance of 15 m had the same ranking as the 5m in – 5m out performance measure, indicating that the differences that occurred at breakout were restored again by the swimming part after the swimmers resurfaced. This suggests that the 3 m/5 m in – 5 m out times suffice for investigating the push-off, because these measures only contain the turn phase until underwater swimming. The 3 m/5 m in – 10 m out is interesting to consider when studying the effect of the underwater and stroke resumption phase since this phase includes the transition from underwater swimming to free swimming. The 5 m in – 15 m out time seems the best performance measure to use from a more holistic/general view, since the changes in ranking that occurred at 10 m are no longer visible due to the larger variation associated with the extra 5 m swimming.

CONCLUSION: From these findings it can be concluded that even though there is a high level of agreement between fixed distance-based turn performance measures, subtle differences exist between the performance measures in that different performance measures are sensitive to different turn phases. This implies that, from a global, correlative perspective, it does not matter much which performance measure is used precisely, whereas from a more specific, local research perspective, pertaining to the phases of the tumble turn, the choice of performance becomes more sensitive. As it stands, more research is needed to further detail this sensitivity.

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