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Dynamic Signature for Tumble Turn Performance in Swimming

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Abstract

The primary aim of work presented within this paper was to establish characteristics seen in acceleration which pertained to phases of the tumble turn. To achieve this, a subject performed a 400m freestyle swim as part of their normal training session during which time they were asked to wear a wireless accelerometer in the small of their back. In addition video data of the turns was captured using a fixed underwater camera. Acceleration data was aligned with video to enable turning phases to be distinguished to facilitate more comprehensive analysis of the turn.

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1. Introduction

Swimming events can be broken into three contributing factors, the start, free swimming and turns. For three events in the Beijing Olympics the contribution of the turns was analysed. The events observed were the 50m, 100m and 200m freestyle women’s races. Turn time was defined as the time from 5m into and 10m out of the turn. It was found that for this example a 1% improvement in turning performance would affect the podium placing in the 100m event for 1st and 2nd places. More significantly it would change the entire finishing places in the 200m event, where a 1% improvement equated to 0.24s, which was greater than the time difference between each of the finishing times of each of the podium positions. In the case of the 200m race this contribution was 21% of total race time.

It is conventional to divide the turn into phases to facilitate more specific analysis. In swimming there are two types of turn, the tumble turn and the open turn. Tumble turns are used for both freestyle and backstroke events where the swimmer performs a forward roll on approach to the wall and kicks off with only their feet. The open turn is used in butterfly and breaststroke events where the swimmer touches both hands on the wall and then kicks off with their feet.

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A review of current research into turn technique has been presented in Figure 1. Research reviewed was predominantly focused on the tumble turn technique, as this was the focus for this paper. For this reason papers have been categorised into phases relevant for this type of turn. These phases translate directly to the open turn with the exception of the rotation phase and the wall contact phase which is divided into hand and foot contact as in Tourny-Chollet 2002 [5]. Typical measurements and values have been summarised in figure 1. The phases of the turn have been defined as approach, rotation, wall contact, glide and stroke preparation. Techniques used included hand timing, manual digitisation of video and collection of force data from instrumented turning walls. All papers relied on manual vision techniques and hand timing to ascertain the overall measurement of performance, whether this was round trip time (RTT) or velocity out of the turn. The major limitation of these techniques is that they are costly in terms of time and operator input and suffer from inherent variability due to their reliance on human judgment.

The number of papers found pertaining specifically to swimming turning performance suggest that there is only a limited focus and understanding associated with the turning phase of swimming. Papers reviewed relied on manual vision analysis techniques to establish measurement parameters, with some testing supplemented with force plate...
analysis. It was found that of all the phases defined in turning, the rotation was addressed the least in literature reviewed.

Emerging technologies in swimming research have begun to address the shortcomings of current accepted methods. These systems look at using non encumbering, swimmer worn ‘nodes’ to monitor performance, using sensors such as accelerometers [8, 9, 10]. Papers reviewed presented validation of the use of accelerometers for the specific analysis of swimming. It was reported that accelerometer data, mounted on the small of the back, could be analysed to derive lap count and timing to +/-1s in 90% of cases, stroke rate, stroke count to +/- 1 stroke for 90% of cases and stroke recognition for 95% of trials [10].

Research to date supplied confidence in the usefulness of accelerometer data for the performance analysis of swimming. Solutions showed that algorithms could be used to successful monitor parameters such as stroke rate and duration, without the need for manual vision analysis techniques, which would be traditionally used. This meant that analysis of multiple parameters could take less than a second not minutes or tens of minutes which was associated with vision techniques. In addition to this results would have a greater reliability as consistent techniques would be used to derive performance parameters and would no longer rely on human judgement. The use of acceleration data for free swimming has been proven, however, specific work on their application for starts and turns analysis has not yet been addressed. Research presented in this paper works towards characterising acceleration collected from swimming tumble turn performance and identifying features corresponding to the phases of the turn. This enabled real time analysis of turning performance to be derived using reliable techniques without the need for skilled operator input.

2. Methods

An amateur level triathlete performed a 400m freestyle swim as part of their normal training session during which they wore a wireless accelerometer in the small of their back. The accelerometer was oriented such that x, y and z accelerations represented forward, lateral and vertical movements respectively. Data was recorded at a sampling rate of 50Hz. In addition, video data of the turns was captured using a fixed, underwater, colour camera operating at 25fps. The primary aim of testing was to establish characteristics seen in acceleration which pertained to phases of the tumble turn.

3. Results

To better understand acceleration data from the node, underwater video of a swimmer turning was digitised, see figure 2. Every three frames a point approximating to the small of the back, i.e. where the node was mounted, was recorded. From this point the velocity and subsequently acceleration was derived relating to the horizontal direction of the swimmer. As the swimmer approached to turn the acceleration was relatively constant, as would be expected in free swimming, with some undulating during the various phases of the stroke. The swimmer’s acceleration then reduced significantly and became negative as they slowed to rotate, this represented the stage where the swimmer velocity reduced to enable them to change direction. As the swimmer pushed of the wall they produced a higher acceleration than during the free swim phase. After the push off they glided and then returned to free swimming where their acceleration returned to fluctuating about a point.
It was important to note that when digitising the image the coordinate origin remained stationary, i.e. x was always left to right on the image. This was different to what would be experienced by the node, as the coordinate system on the node would move with the swimmer. The digitised turn allowed a better understanding of the swimmer in acceleration space, which is more difficult to comprehend than considering position or velocity.

![Digitisation of a swimming tumble turn](image)

Video and acceleration data obtained during a turn were then aligned, see figure 3. The ‘turn’ phase was defined in acceleration space as the time between the last arm stroke prior to and the first arm stroke after the turn. These events could be distinguished from y axis acceleration characteristics, where clear stroke cycles were observed. The signal, visually, shared similarities with the digitised acceleration. Coordinate axes were positioned on the small of the back of the swimmer to better understand the acceleration contribution from gravity. The z axis was first observed as this axis experienced the most prominent signature, compared with the x and y. As with the digitised video, the acceleration on approach to the turn was fairly constant, fluctuating with the stroke cycle. This was consistent with the video as the coordinate system is largely oriented the same way, however the accelerometer signal fluctuated about 1g due to gravity. The affect of gravity on the accelerometer was such that when a given axis is placed perpendicular to gravity it read 1g, i.e. 9.81m/s/s. This meant that the orientation of the accelerometer was responsible for the overriding signal produced, as the contribution from gravity produced a significantly bigger acceleration than the acceleration the swimmer generated.

As the swimmer initiated the turn they rotated through to where the coordinate axis had turned through 90 degrees. This meant that the component of gravity was removed from the z axis and instead was seen on the x axis. This can be observed where the acceleration signal reduces to a figure close to zero. i.e. As the swimmer turns onto their back during the turn rotation the contribution of gravity on the z axis becomes negative, compared to when the swimmer initiated the turn in a prone position. Once the swimmer starts to rotate back to a prone position the acceleration returns to fluctuating about 1g, where it was initially. This motion was observed as a negative peak, where the start...
of the rise could be used to determine the point where the swimmer started to rotate off their back. Data collected from a number of turns were analysed by discriminating between each phase, i.e. the approach, rotation and glide phase. It was found that for the swimmer tested averagely, 46% of the turn was spent in the approach phase, 32% in the rotation and 22% in the glide.

Figure 3: Acceleration data of a tumble turn

1. Approach turn, z acceleration is fairly constant fluctuating about 1g (acceleration due to gravity).
2. Initiating the turn, z rotates through 90°, such that x experiences the major g component and z will tend towards zero.
3. As swimmer turns onto their back the z component becomes reversed from the free swimming prone position and therefore experiences a negative contribution from g.
4. As swimmer rotates back onto their front the z acceleration returns to fluctuating about 1g.

Figure 4: SPC chart for glide times
Statistical process charts (SPC) were used to plot the time taken for each of the phases identified during the turn. Each turn analysed was within two standard deviations of the average approach time. The variability may give an indication of swimmer consistency and subsequently performance or ability. Rotation time was more closely distributed about the mean with only three turns falling above one standard deviation either side. Rotation in the first turn was quicker than all other turns, this was also seen in the approach time and could be attributed to ‘going off too fast’. A longer final rotation suggested fatigue or the swimmer winding down. Glide time displayed the greatest point of interest because, with the exception of turn nine, all of the turns were closely distributed about the mean, either within or very close to a one standard deviation difference. Dive nine, however, fell outside two standard deviations from the mean, suggesting something different happened for this turn, see figure 4. The use of SPC charts allows differences to be flagged and action to be taken to explain these events and implement changes. This kind of analysis may be appropriate, for example, when monitoring long distance swimmers to observe the effect of fatigue on turn performance and whether these effects are seen in any particular phase.

4. Summary

A wireless node was used to provide acceleration data regarding turning performance. Using vision data it was possible to determine turning phases based on acceleration characteristics. This enabled more complete analysis of turning performance as the approach, rotation and glide could be individually identified. SPC charts were used to display results and were found to be useful in flagging significant events, such as in turn nine where the glide phase was substantially longer than in any other turn. This data representation was thought to be an easily understandable method that could be proactive in alerting users to events, rather than the coach or biomechanist having to analyse every output to judge whether something is of significance.

References


