# Accelerometer Profile Recognition of Swimming Strokes (P17)

**Chapter** · August 2008

DOI: 10.1007/978-2-287-09411-8_10



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# ACCELEROMETER PROFILE RECOGNITION OF SWIMMING STROKES

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**TOPICS:** Sailing/Water Sports, Measurement Systems

**Abstract:**

The use of technology in sports performance analysis is a rapidly increasing practise. Tools for analysis aim to provide useful information to supplement coach knowledge and improve feedback in the development of athletes. In swimming the use of subjective video analysis is wide-spread, however, unlike some other sports, there are few quantitative measures of performance. Quantitative measures, such as intra cyclic variations of stroke characteristics, have the potential to provide more specific performance metrics from which to make improvements. Such measures are currently not widely available to coaches, support staff and swimmers, due to the infancy or lack of sufficiently developed technologies.

The research outlined in this paper has explored the relationship between stroke characteristics and how they are represented by accelerometer data. Each of the four competition swimming strokes has been investigated, where swimmers instrumented with a portable sensor were asked to perform their normal swimming strokes. During each swimming trial, sensor and video data were recorded. Preliminary testing has shown that accelerometer data can be useful in the determination of simple stroke characteristics, for example stroke rate and duration, and that differences in profiles can be attributed to a certain stroke or swimmer. Future work is required to broaden this understanding and support the outcomes already generated from this preliminary study.
**Key words**: swimming, accelerometer profile, stroke recognition

## 1- Introduction

Performance monitoring and analysis in sport plays a key role in the development of athletes at any level. Swimming is a discipline built from a number of skill sets and movement profiles, which together contribute to overall performance. The ability to scrutinise each of these skills in detail could enable significant improvements in performance to be made. In swimming, performance analysis techniques are predominantly visually-based and require post processing of recorded images to derive quantitative and qualitative measures of performance. There is currently a gap in direct, (i.e. non derived), quantitative analysis methods developed specifically for swimming performance.

Analysis tools based upon the integration of distributed sensors e.g. accelerometers may be able to give valuable information regarding the breakdown of swimming strokes and their performance related characteristics ([DA1], [DJ1], [IO1], [JD1], [O1], [OY1], [OI2], [T1]). These methods are not yet widely used amongst the swimming community as tools for analysis. This can be attributed to a combination of lack of development and refinement of the technologies used and a lack of understanding regarding how to process the data into a useful and useable format.

Preliminary testing has been undertaken to start to address these gaps in knowledge. Testing was carried out to establish the types of relationships found between accelerometer trace characteristics and swim stroke characteristics. Results were broken into two areas of interest addressing two research questions:

 

- Can accelerometer data be used to identify swimming stoke characteristics such as stroke count and stroke duration?
- Can accelerometer trace characteristics be attributed to a certain stroke or swimmer?

## 2- Experimental Protocol

Two swimmers were instrumented with a three-axis accelerometer (Freescale Semiconductors) attached to the small of the back with the axes oriented as marked in Figure 1. In the prone position the x-axis represented forward motion, the y-axis was sideways roll and the z-axis was up and down undulation. Swimmer 1 was a university swimmer of national competition standard and swimmer 2 was a national team squad swimmer of international competition standard. A Panasonic AG-HV200E camera was used to digitally record both swimmers performing each of the four competition strokes that were performed in an individual medley format (IM), Figure 2. Data from the accelerometer was sampled at 100Hz and downloaded to a central computer for post processing.

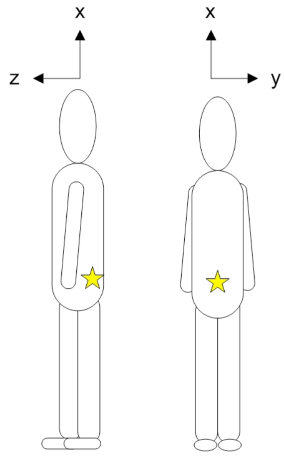


**Figure 1 - Orientation of accelerometer on the swimmer.**

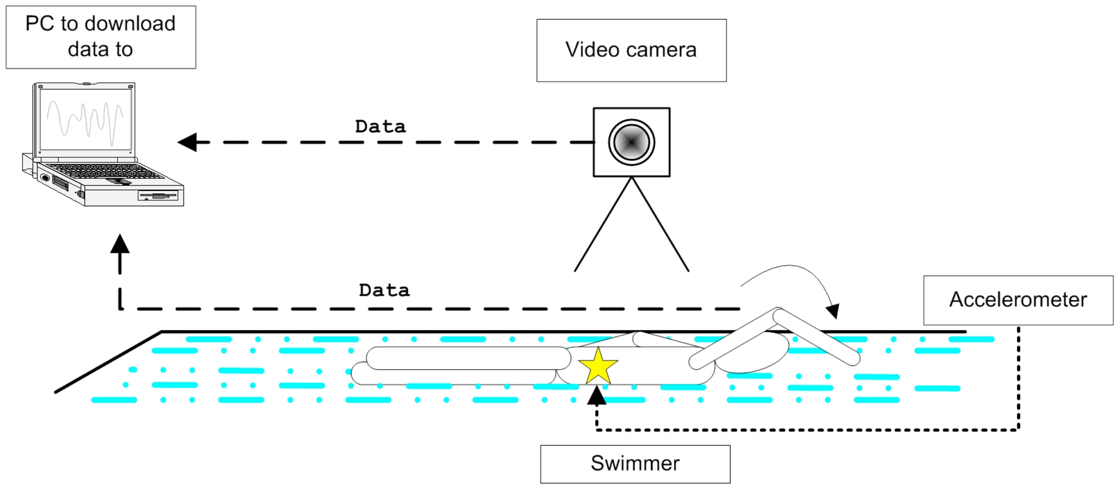


**Figure 2 - Testing set up.**

The three axes of acceleration were measured in relation to gravity (g) however the orientation of the sensor during the trial was not known, due to the absence of an inclinometer or similar complimentary sensor. Therefore the influence of gravity on the sensor varied throughout the trials. Despite this limitation the same accelerometer unit and the same set up for both trials was used to ensure consistency in testing such that relative measures of acceleration could be confidently assumed.

## 3- Results

Video and accelerometer data were synchronised and comparisons were made between the stroke count and duration as measured from the video and accelerometer data. Data from the x-axis was used to evaluate the butterfly and breaststroke and from the y-axis for backstroke and freestyle, as a strong cyclic pattern was found in the generated data. Stroke rate was distinguishable on the accelerometer traces as cyclic patterns of acceleration, see Figure 3. For each trial the stroke count per length was measured using manual observation of the video and cyclic counting techniques from the raw accelerometer data. Total stroke counts measured on the video and accelerometer were found to be equivalent throughout all trials. Stroke duration was measured for both swimmers. A distinct point in the stroke cycle was identified, e.g. hand entry for butterfly, and used to measure the start of each new stroke when analysing stroke duration from the video data. Accelerometer data was divided similarly using recurrent peaks to establish stroke cycle, Figure 3 .The average difference between video and accelerometer measured stroke duration was 0.056s and 0.077s for swimmer 1 and 2, respectively. This equated to an overall average of 0.067s, or less than two frames difference, when operating a standard video camera, i.e. running at 25 frames per second (fps).

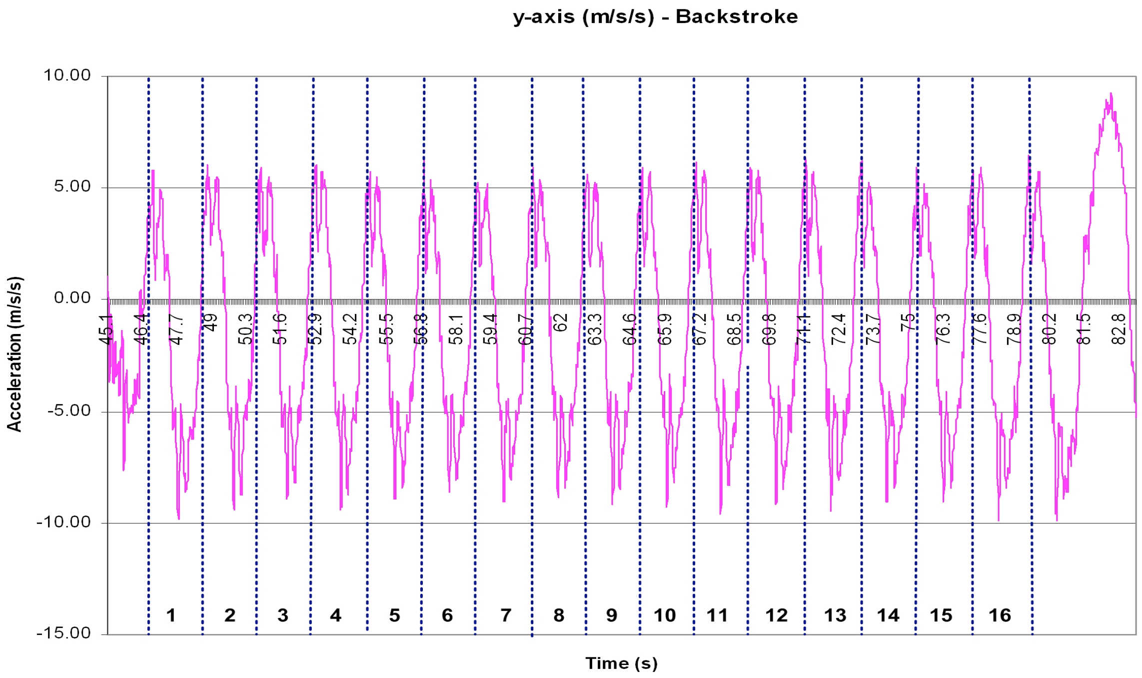


**Figure 3 - Graph showing backstroke acceleration profile, broken into individual strokes using cyclic patterns for recognition.**

Further analysis was carried out to establish whether the shape of the accelerometer data profile could be related to a given stroke or swimmer. Key areas of interest were identified as:

- Magnitude of acceleration (amplitude)
- Duration of stroke (wavelength)
- Range of acceleration values
- Standard deviation of accelerations
- Profile shape

The raw accelerometer data shown in Figure 4 demonstrates with clarity the variability of the four IM strokes in terms of acceleration characteristics. Each stroke can be identified by a unique combination of x,y,z accelerations from the raw data collected. Similar comparisons can also be made by considering differences in profile parameters for individual axes of motion, when considering the magnitude of acceleration, stroke rate and major axis of acceleration.

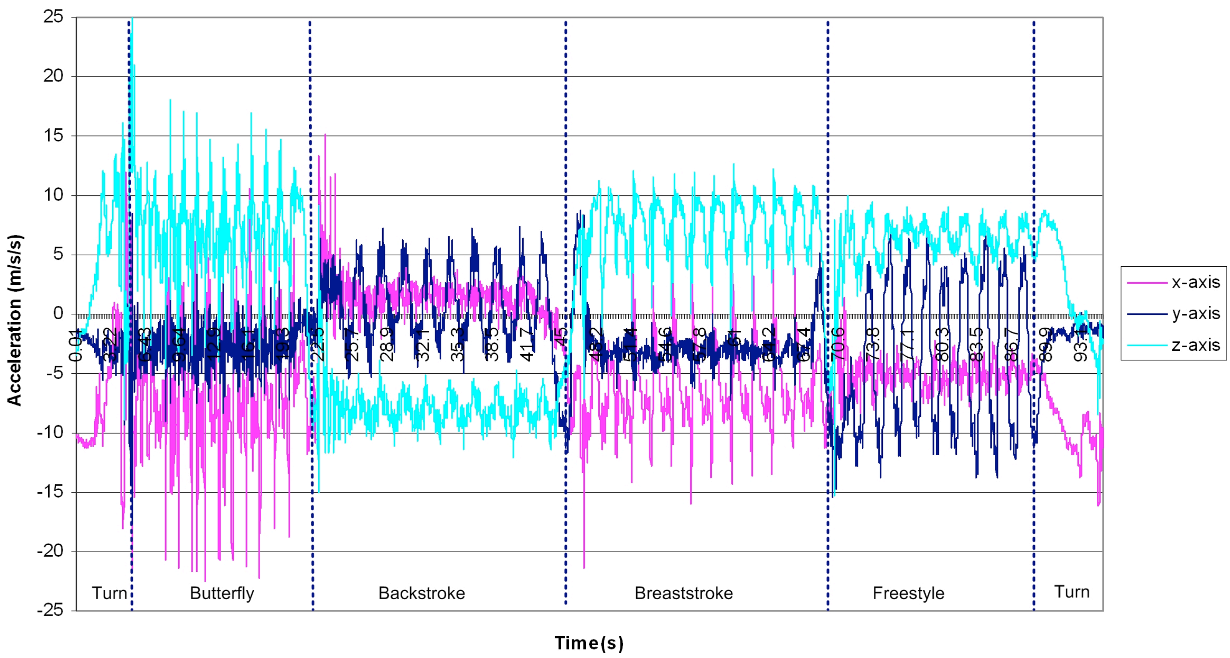


**Figure 4 - Graph representations for accelerations in x for breaststroke and freestyle trials. 'Typical profile pattern' shown to the right of the graphs.**

The variability within stroke acceleration characteristics between the different swimmers was also considered. Using two examples from the trial, comparisons of each swimmer's stroke characteristics were analysed and used to provide assumptions about their technique.

The analysis of accelerometer data for the butterfly trial showed that swimmer 1 produced a standard deviation of 4.85 m/s/s, conversely swimmer 2 had a lower standard deviation of 3.96 m/s/s, which signified a smaller variability in intra-stroke acceleration in the forwards direction (x-axis). This may imply that swimmer 2 has a smoother stroke technique. In addition, this suggests that swimmer 1 experiences a greater contrast in forward acceleration during the stroke cycle whereas swimmer 2 presents a more constant acceleration throughout the stroke. A conclusion that may be drawn from this, is that swimmer 2 demonstrates a greater ability to maintain propulsion during the stroke whereas swimmer 1 suffers from large decelerations during the recovery phase implying a less efficient stroke technique.

Breaststroke trials showed strong similarities between the two swimmers, with respect to the range of accelerations being measured and the standard deviation values (28.14 m/s/s and 26.63 m/s/s for the range of acceleration measured and 2.95 m/s/s and 2.87 m/s/s for the standard deviations for swimmer 1 and 2 respectively). This indicates a greater consistency in their stroke characteristics for breaststroke from an acceleration perspective. Graphical representation of the two traces, see Figure 5, has also demonstrated a clear correlation in the acceleration profile shape. Despite these close parametric similarities the two swimmers may be distinguished from one another by considering variables such as the stroke duration and the magnitude of accelerations. The increased convergence in acceleration data for breaststroke specifically may be attributed to it being the preferred stroke for swimmer 1 and therefore their standard in this discipline may be closer to the generally higher overall standard of swimmer 2.

 

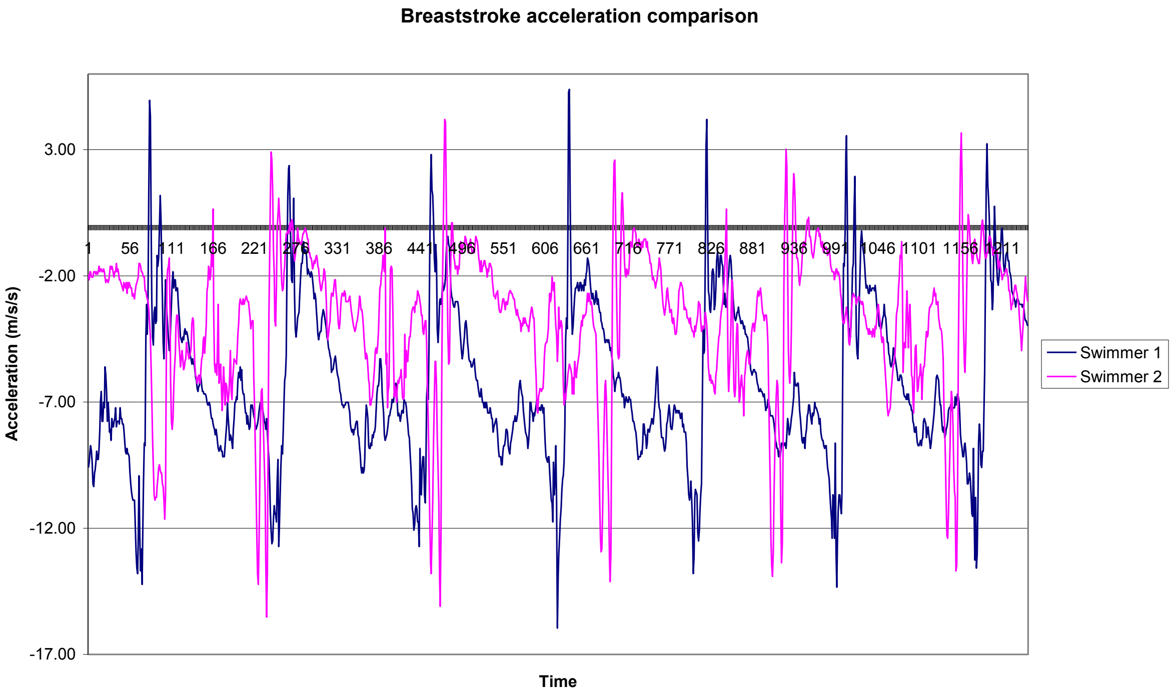


**Figure 5 – Graph showing a comparison of breaststroke traces for two different swimmers.**

## 4- Conclusions

The results presented within this paper have been taken from testing that was carried out to establish the types of relationships found between accelerometer trace characteristics and swim stroke characteristics for different swimmers. The results have been broken into two areas of interest addressing the research questions identified in the introduction. Accelerometer traces established from IM trials were analysed with relation to these research questions. It was found that data collected for both swimmers in all trials could be used to extract simple stroke characteristics, namely, stroke rate and stroke duration. The resolution of these measures was found to be within 0.067 seconds of equivalent measures taken from manual analysis of the corresponding videos images.

Further analysis was carried out to ascertain whether specific accelerometer characteristics could be attributed to a given stroke. Simple visual representations of data collected from the trials demonstrated clearly distinguishable characteristic variability that could be accredited to the four IM strokes. Further analysis of data is required to correlate phases of the stroke cycle with patterns in acceleration cycles. This may be used to better determine features that can be exclusively qualified to a specific stroke.

Comparisons of data were made between the two swimmers for each of the IM strokes. Profiles for each swimmer were distinguished from one another by considering variables such as magnitude of acceleration, stroke duration and standard deviation of accelerations. Discrepancies between the data collected for each swimmer may correspond to differences in competency in terms of technique and can help to provide information from which improvements can be made in the future.

Preliminary testing has shown that accelerometer data can be useful in the determination of stroke characteristics. Future work is required to broaden this understanding and support the assumptions generated from this preliminary study. Development of hardware such that orientation of the sensor is known should also be addressed to enable a more detailed understanding of data produced. Broader testing with a larger number of swimmers, of all standards, will also generate further confidence in any conclusions which have been drawn.

## 5- Acknowledgements

The authors would like to thank the sports scientists, coaches and swimmers at Loughborough University who have taken part in the information gathering stages of this research. Funding for this work has been provided by the Innovative Manufacturing and Construction Research Centre (IMCRC) based at Loughborough University, part of the Engineering and Physical Sciences Research Council of Great Britain (EPSRC), and UK Sport.

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