IDENTIFICATION OF THE POP-UP ACCELERATION WAVEFORM SIGNAL: A CASE STUDY

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The purpose of this case study was to assess the feasibility of using accelerometers to identify and analyse the acceleration waveform signals of the pop-up movement. An experienced male recreational surfer performed 10 dry-land pop-ups with accelerometers (1000 Hz) attached to the sacrum and lateral aspect of each shank. The waveform signals of the pop-up were successfully identified at each instrumentation site using a combination of acceleration and video data. Several movement events that occurred during the pop-up were also able to be detected within each of the mean resultant acceleration signals. These findings suggest that accelerometers can viably be used to detect and analyse the waveform signals of the pop-up. This provides initial evidence that accelerometers are a suitable tool for collecting kinematic data of surfing performances.

KEYWORDS: accelerometers, pop-up, surfing, acceleration, waveforms.

INTRODUCTION: The challenges imposed by the environment means that biomechanical data related to surfing performances are difficult to capture (Bruton et al., 2013). Nonetheless, the ability to acquire this data effectively may provide valuable information regarding athlete workloads, manoeuvre executions and injury prevention. GPS and video analysis have been used in the past to track surfing activities and provide some insight into manoeuvre performances (Farley et al., 2017). However, GPS can sometimes be inaccurate or unreliable and video analysis can be a very time-consuming process (Gray et al., 2010, Petersen et al., 2009, Witte and Wilson, 2004). Ideally, an automated system that makes use of wearable technologies is needed to provide a more accurate and efficient means of capturing surfing-related data.

One way that this may conceivably be achieved is by employing accelerometers along with machine learning methods to collect and then identify and isolate the acceleration waveform signals of specific surfing activities, events, manoeuvres and movements. This approach could provide greater insight into the kinematics of certain limb and body segments during surfing-related tasks, while also more efficiently determining event counts, durations and other workload data. If this data capture approach is to be realised in the future, initial feasibility studies need to occur to verify whether the accelerometer output signals can effectively be used to identify the acceleration waveforms of surfing-related tasks. To limit the effect of external variables and noise on the accelerometer outputs, and to enable the researchers to more discretely capture the waveform signals, these studies should initially take place within a controlled laboratory setting.

Although the majority of surfing tasks cannot be performed out of the water, the pop-up is one skill that can reasonably be executed on land (Eurich et al., 2010, Parsonage et al., 2018, Parsonage et al., 2017) – making it a viable manoeuvre to be tested in the lab. The purpose of this case study was to explore the feasibility of using accelerometers to identify and analyse the key features of the pop-up acceleration waveform signal within a lab-based setting. As this movement is unique to the sport of surfing and its successful performance is essential for wave-rides to commence (Eurich et al., 2010), its waveform signal may also prove to be useful for detecting the start of wave-rides in the future.

METHODS: An experienced male recreational surfer (age: 26 years, height: 1.85 m, mass: 74.1 kg) volunteered to perform 10 dry-land pop-ups in the USC biomechanics lab. The pop-up is a highly dynamic skill that requires the surfer to move through all three planes of motion to transition from prone to a sideways, semi-crouched standing position on the surfboard (Eurich et al., 2010, Loveless and Minahan, 2010). The GENEActiv™ Action model triaxial accelerometers (Activinsights Ltd., Cambridgeshire, UK) were used to track acceleration signals of the sacrum (S2) and front and back shanks (positioned on the lateral surface halfway between the lateral femoral epicondyle and the lateral malleolus). The accelerometers (1000 Hz) were attached to the participant using Velcro® straps and secured using rigid sports tape to limit any vibrations or movement of the devices during testing. A shortboard surfboard, with the fins and leg-rope removed, was placed on top of two gymnastics landing mats so that it sat off the ground and allowed for simulated paddling strokes to occur prior to performing the pop-up. A video camera (25 Hz, JVC Kenwood Corporation, Yokohama, Japan; model: Everio GZ-EX255BAA) was used to capture all pop-up trials in order to aid with the accelerometer data extraction and analysis, while Kinovea video analysis software (version 0.8.27, Charmant, J., 2018) was used to analyse all of the video data.

Prior to the trials, a 10 s static capture was performed in order to help synchronise the video footage with the accelerometer signals so that accurate data extraction of each trial was possible. Pop-up trials began with the participant adopting the prone paddling position on the surfboard, before a loud "beeping" noise signalled the start of the capture. The participant then performed three to four paddling strokes before commencing the pop-up movement. The trials were conducted at a self-selected pace and no performance instructions were provided to ensure that each capture was the natural pop-up technique of the participant. The acceleration data were extracted from each device using the GENEActiv PC software (version 3.3, Activinsights Ltd., Cambridgeshire, UK, 2019). These files were then filtered (by applying a second-order high-pass Butterworth digital filter with a cut-off frequency of 12 Hz) and the resultant acceleration values calculated for each time-point using a written script in R before the data was analysed further.

The pop-up waveform signals were identified using video footage of the testing session and visual inspection of the acceleration time-series data. The approximate *start* and *end* timestamps of each of the 10 s static captures within the video and accelerometer data were first compared in order to estimate the time drift between the camera and the devices. Taking the estimated time difference into consideration, the video timestamps corresponding to the *start* of each of the ten pop-ups were then used to approximate the location of each of the pop-ups within the acceleration data. The *start* of the pop-up was determined by visually identifying the video frame in which the participant (in the prone position) initiated the upward pushing-movement of the upper-limbs (particularly the commencement of elbow extension), which eventually enabled the head and lower-back to rise from the surfboard. The location of each of the pop-ups within the accelerometer data was then confirmed by graphically identifying the sacral resultant acceleration waveform peak that occurred immediately after the signal had been in a period of constant acceleration (around 1 *g*) and was close to the *starting* timestamp established from the video data. The *start* of each of the ten pop-ups was then more accurately defined as the time-point in which the sacral resultant acceleration signal initially reached a threshold above 1.1 *g* prior to the first peak in the waveform. The remaining movement events were then identified within every pop-up trial using the video footage. For each of these, the stopwatch tool in Kinovea was used to record the time (to the nearest hundredth of a second) from the *start* of the pop-up to the specific movement event. This temporal data was then used to identify every movement event across each of the 10 pop-ups within the acceleration data.

All pop-up acceleration data are presented in gravitational acceleration units (*g*) and have been time-normalised to 1001 data points. Time-series plots appear as the mean of all trials ± the 95% confidence interval (CI) at each normalised time-point.

RESULTS: The sacral and front and back shank mean resultant acceleration waveform signals for the pop-up are highlighted in Figure 1. The major movement events, which were identified through analysis of the acceleration and video data, include the *start*, *push-up*, *peak sacral vertical displacement*, *double-foot contact*, *sacral dip*, and *end*. These events occur at approximately 0%, 20%, 45%, 54%, 70% and 100% of the pop-up movement (Figure 1).

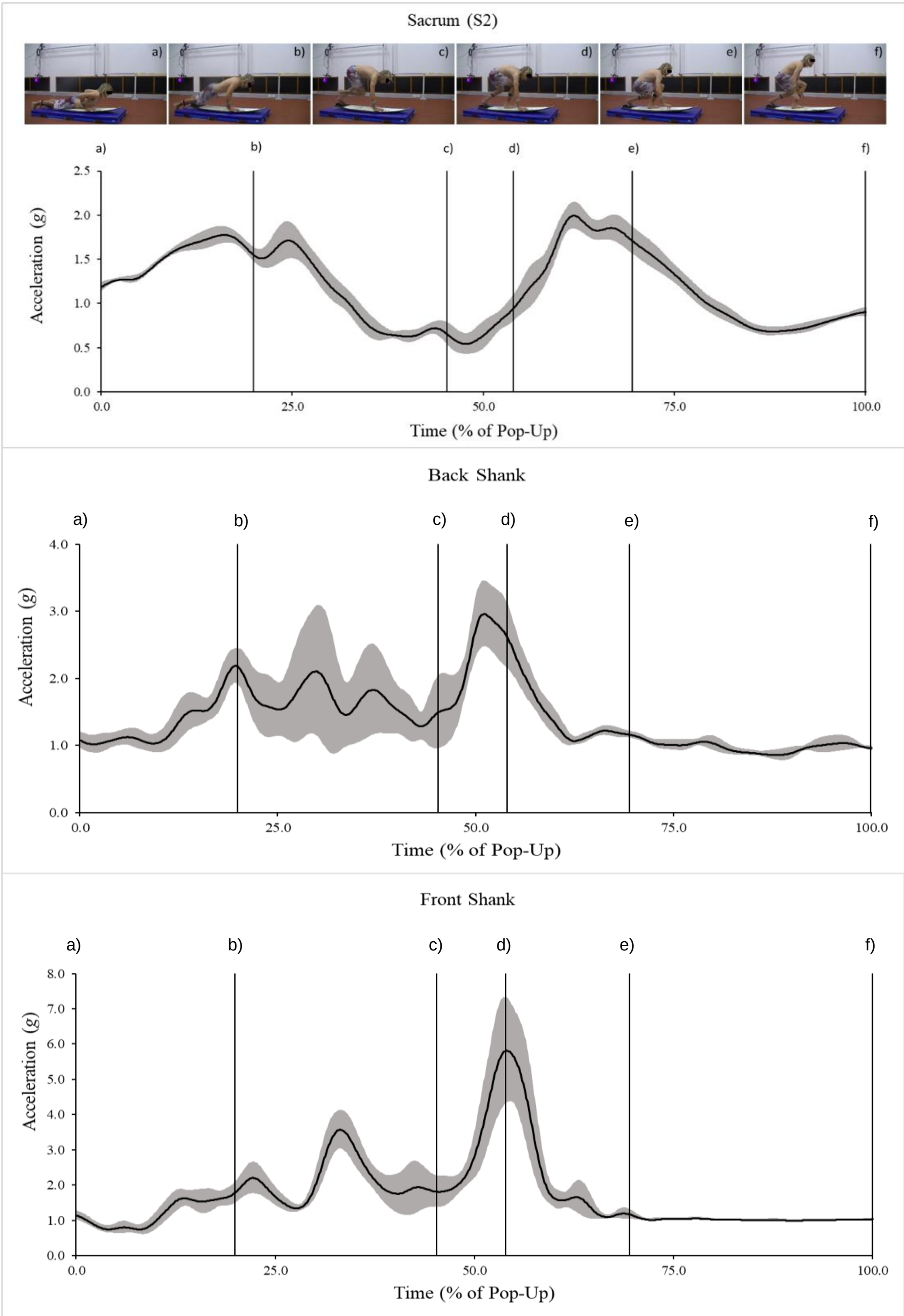

Figure 1: Movement events associated with the pop-up as highlighted on the mean resultant sacrum and front and back shank acceleration (*g*) waveform signals. Letters denote the following movement events: a) start, b) push-up, c) peak sacral vertical displacement, d) double-foot contact, e) sacral dip, f) end.

DISCUSSION: As far as the authors are aware, this is the first study to assess the feasibility of using accelerometers to identify the acceleration waveform signals of the pop-up movement in a lab-based setting. The research findings suggest that accelerometers can viably be employed to help detect and analyse movement features of the pop-up waveform signals across several instrumentation sites. However, it should be noted that this was only made possible with the aid of video analysis techniques. The results indicate that the pop-up does have a distinct and largely consistent acceleration waveform signal at each of the attachment sites. The latter can be seen via the relatively moderate ranges of the 95% confidence intervals on each of the mean resultant acceleration time-series plots – with the back shank accelerations likely the most variable across all the trials. This implies that the pop-up acceleration waveform signals may be used in the future to help detect the start of wave-riding events within a given surfing session. Although this is the case, as this study only analysed the pop-up performances of a single participant, there may be a question of the transferability of the acceleration waveform signals to other surfers. Additionally, the participant was reasonably reliable in terms of the phases of acceleration that each of their measured segments experienced during the pop-up performances. The pop-up movement events that were outlined within this study were comparable to those previously reported by Hammer and Loubert (2010). Similarly, the percentage of time values, which indicate when each of these movement events occurred during the pop-up, were also like those described by Hammer and Loubert (2010). Overall, these findings provide evidence that accelerometers are likely a suitable tool for collecting kinematic data of surfing performances. In particular, it seems that body and limb acceleration waveform signals may be used to identify specific surfing activities, events, manoeuvres and movements. However, further research is necessary in order to identify the acceleration waveform signals of other surfing manoeuvres and to create a more automated system of detection.

CONCLUSION: The successful identification of the acceleration waveform signals of the pop-up movement provide evidence that accelerometery can feasibly be used to capture and analyse performance-related surfing data. The pop-up's waveform signals may also prove to be useful in the future for detecting the start of wave-riding events within substantially larger accelerometery datasets captured during surfing sessions. Although the findings of this study are encouraging, much research still needs to be conducted before accelerometers can effectively and efficiently be used to automatically track and analyse surfing performances.

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