Scoring Analysis of the Men's 2014, 2015 and 2016 World Championship Tour of Surfing: The Importance of Aerial Manoeuvres in Competitive Surfing.

Research conducted at Hurley Surfing Australia High Performance Centre

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ABSTRACT

The aim of this study was to investigate the impact of aerial manoeuvres on scoring in professional surfing. 23631 waves were analysed for the number and types of aerial manoeuvres performed from the 2014, 2015 and 2016 Men's World Championship Tour. Additionally, the awarded score, timing and order of the aerial was also analysed. Descriptive statistics and Two Way ANOVA's were performed with Sidak Multiple Comparisons Post Hoc analysis. Results were a significantly higher score being awarded ($P \leq 0.0001$) when including an aerial in competition across all three seasons. In 2015 surfers were awarded a significantly larger score when performing an air reverse, compared to 2014 ($P=0.0002$) and 2016 ($P=0.0057$). Surfers were also awarded a higher score for the full rotation aerial in 2015 compared to 2014 ($P=0.0177$). In 2015 surfers performing forehand aerials were awarded a greater score than in 2016 ($P=0.0113$). The timing of the aerial and score awarded was significantly greater in 2015 as opposed to 2014 when the aerial was their final manoeuvre ($P<0.0001$) and when surfers timed the aerial performance early within the heat ($P=0.0027$). If a surfer incorporates an aerial manoeuvre during competition, generally speaking, they will be awarded a significantly higher score.

Keywords: Notational Analysis, Performance, Awarded Score, Coaching Impact

INTRODUCTION

In competitive surfing, the athlete's performance on each wave surfed is subjectively assessed on a scale of 0-10 points by a panel of 5 accredited judges. The judge's score is based on five key elements: 1) commitment and degree of difficulty; 2) innovative and progressive manoeuvres; 3) combination of major manoeuvres; 4) variety of manoeuvres; and 5) speed, power and flow (World Surf League [WSL], 2014). For a surfer's performance to be awarded a higher score, a combination of manoeuvres that address the 5 key elements in the most critical sections of the wave must be performed (Lundgren, Dunn, Nimphius, & Sheppard, 2013; Lundgren, Newton, Tran, Dunn, Nimphius, & Sheppard, 2014). The surfer with the highest two-wave total is deemed the winner of the heat. One of the most highly regarded manoeuvres in competitive surfing that has been linked with high performance and high risk is the aerial (Lundgren et al., 2014). The aerial manoeuvre incorporates the surfer launching themselves above the top of the wave then landing back on the same wave to continue their ride (Ferrier, Sheppard, Newton, & Nimphius, 2014).

The importance of the inclusion of an aerial manoeuvre was highlighted previously by Peirão and dos Santos (2012) during two Association of Surfing Professionals (ASP) competitions in 2007 and 2010. The study reported that the performance of an aerial manoeuvre when incorporated with a series of other manoeuvres had a low but significant correlation (r = 0.30; $P \leq 0.001$) with wave score. Additionally, our research team (Lundgren et al., 2014) also reported that surfers including an aerial manoeuvre during competitions were awarded an average score of 7.40 (±1.53) out of 10. In comparison, the same study highlighted that rides not including an aerial were on average, awarded a significantly lower (P<0.001) score of 5.08 (±2.21) during the 2012 ASP World Championship Tour. A recent study by Forsyth, de la Harpe, Riddiford-Harland,

Whitting, & Steele (2017) agreed with both previous studies reporting that during the 2015 World Championship Tour (WCT), surfers who included an aerial manoeuvre were awarded a significantly greater score than when they just performed manoeuvres on the wave face.

An interesting observation from the earlier study by Lundgren and associates (2014) was the aerial completion rate during competition. The authors highlighted that during competition, the completion rate of an aerial in competition was below 50% (Lundgren et al., 2014) outlining that it may be deemed a high risk manoeuvre to perform. Even with this low success rate, the three highlighted studies indicate that the inclusion of an aerial may still have a major influence on scoring potential. Tesler (2011) suggested that when a surfer includes an aerial manoeuvre whilst performing in competition, there is an inherent risk of either a wipe out or incomplete ride, thereby resulting in a lower score for that wave. However, with the recent changes to the scoring criteria, the risk and athleticism required to perform an aerial manoeuvre pairs itself well in the competitive situation, creating a risk-reward status for the surfer and their wave score when including an aerial manoeuvre. Recently, it has been observed within competition that the performance of an aerial alone (i.e. no other manoeuvres on that wave) can be deemed by the judges to address all the components of the judging criteria, and can be awarded the maximum 10 available points (Tesler, 2011).

Earlier, it was outlined by Farley, Raymond, Secomb, Ferrier, Lundgren, Tran, Abbiss, & Sheppard (2015) that the majority of studies in performance surfing have mainly focused on the physiological requirements (Farley, Harris, & Kilding, 2012), anthropometric variables (Barlow, Findlay, Gresty, & Cooke, 2014) and paddling performance (Sheppard, Osborne, Chapman, & Andrews, 2012) of elite level surfers. Such research has made major inroads into understanding the fitness requirements and physical attributes required for elite level competitive surfing. However, so far there is

limited published research regarding performance analysis in international competition and how the surfers choice of manoeuvre can influence scoring potential (Ferrier et al., 2014; Forsyth et al., 2017; Lundgren et al., 2013, 2014; Peirão and dos Santos, 2012).

Therefore, the aim of the current study was to investigate whether the inclusion of an aerial manoeuvre during competition continues to have a positive impact on scoring potential and whether this trend is evolving. The researchers sought to further investigate if the effect of aerial variation, order of manoeuvre during the surfing performance and timing of the aerial manoeuvre during the overall heat had an influence on competitive performance and scoring potential during the 2014, 2015 and 2016 Men's WCT. The findings of this study have potential to provide an insight into the effectiveness of including aerial manoeuvres in the wave riding repertoire, and whether the inclusion of an aerial manoeuvre and when it is performed during competition positively impacts the score awarded.

METHODS

All data were recorded for the 33 events carried out during the 2014 (n=11), 2015 (n=11) and 2016 (n=11) Men's WCT, where all waves (n=23631) surfed were analysed. Data collection was carried out between the months February 2014 through February 2017 from on-line video content available from the respective events heat analyser function available on the World Surf League website (WSL, 2014). The study and procedures were approved by Edith Cowan University Human Ethics Committee (approval number: 10320).

For each wave surfed, the number of manoeuvres were counted and further categorised as either including an aerial (n=2285) or non-aerial (n=21346). An aerial manoeuvre was classified as when the whole board and athlete's body was clear from the top of the wave, with the athlete's board and body in the air (Ferrier et al., 2014). This did not include a

free fall from a previous manoeuvre. The score awarded for all waves, as well as the awarded score for the waves counted as the surfer's top two scoring waves were noted from the World Surf League website (2014). The waves including a completed aerial attempt were then classified into 9 variations (Table One), with the order the aerial was performed on the wave also recorded. Each heat was divided into 3 equal time segments as heat times can range from 30 minutes to 40 minutes within a competition. This allowed for the calculation of temporal characteristics when each wave including an aerial manoeuvre was performed. Subsequently this allowed the authors to identify if the timing of the wave within the heat, including the aerial attempt, had an influence on scoring potential. In addition, for the 2015 and 2016 seasons, the surfers performance of the aerial was recorded and categorised to either forehand (surfer facing the wave when riding) or backhand (surfers back to the wave when riding) to investigate if the stance had an impact on the score awarded.

*******Table One Here*******

Statistical Analysis

Standard descriptive statistics of mean and standard deviations were calculated. A one-way repeated measures ANOVA was performed to determine significance of difference between aerial score, timing of aerial performance and direction the surfer was facing when the aerial was completed with the year of competition. A within variation two-way ANOVA was carried out to compare the differences in score awarded between years for each aerial variation performed. All data was assessed for normality using a D'Agostino test. In the event of the assumption of normality being violated the Greenhouse-Geisser correction adjustment was used. Where a significant difference was indicated a Sidak Multiple Comparisons Post Hoc Test was used to identify individual statistical variances. The magnitude of differences was evaluated by calculating effect sizes (Cohens *d*).

Magnitude of effect was based on the following criteria: >0.2, trivial; 0.2-0.5, small; 0.5-0.8, medium; and >0.8, large (Cohen, 1988). All statistical analyses were carried out using GraphPad Prism version 7.02 for Windows (GraphPad Software, LaJolla California USA, www.graphpad.com) with statistical significance being set at $P \leq 0.05$.

RESULTS

As outlined in Figure 1, there was a significant difference between the mean scores of the wave rides that incorporated an aerial manoeuvre (6.82, 6.91, 6.74), versus waves without an aerial (6.01, 6.10, 6.25) in the 2014, 2015 and 2016 seasons respectively R^2=0.012, $F(5,7690)$=16.86, P<=0.0001. Of the 2285 waves analysed that included an aerial, 711 aerials were attempted in 2014, 782 were attempted in 2015 and 792 were attempted in 2016. The most common variation of aerial attempted over the three years was the air reverse with 323 attempts in 2014, 455 attempts in 2015 and 447 attempts in 2016 (Figure 2a).

******FIGURE ONE HERE******

The completion rate of the air reverse aerial variation was 51% during the 2014 competitive season, 49% in 2015 and 43% in 2016. The aerial variation with the highest completion rate in 2014 was the straight air with a grab (55%), and in 2015 it was the air reverse (49%). During the 2016 season, the alley oop was the most successful variation with a completion rate of 70%. The variation with the least attempts across all years was the alley oop with grab (4 attempts in 2014, 3 attempts in 2015 and 7 attempts in 2016) with a 0% completion rate for both 2014 and 2015, and a single completion in 2016 (see Figure 2a).

******FIGURE TWO HERE******

The two way ANOVA indicated a significant and small effect difference R^2=0.5855, *F*(2,982)=3.028 in the score awarded between the 2014 (5.83 points ± 2.06 [5.52-6.15] 95% CI) vs 2015 (6.58 points ± 1.74 [6.35-6.81] 95% CI) (*P*=0.0002, *d*=0.39) and 2015 (6.58 points ± 1.74 [6.35-6.81] 95% CI) vs 2016 (6.02 points ± 1.67 [5.79-6.26] 95% CI), (*P*=0.006, *d*=0.32) seasons for the air reverse variation of aerials (Figure 2b). It is further indicated in figure 2b, when the surfer included a full rotation aerial during the 2015 season (8.55 points ± 1.20 [8.05-9.04] 95% CI), they received a significant and moderate increase in score (*P*=0.018, *d*=0.76) as opposed to performing the same aerial in 2014 (7.11 points ± 2.34 [5.69-8.52] 95% CI).

******FIGURE THREE HERE******

When the surfer performed an aerial on their forehand they were rewarded with a significant and small effect increase in score during 2015 (6.78 points ± 1.69 [6.59-6.98] 95% CI) than in 2016 (6.32 points ± 1.73 [6.12-6.52] 95% CI) R^2=0.015, *F*(3,675)=3.426. *P*=0.011, *d*=0.27. As indicated in figure 3, when comparing the scores for waves performed on the backhand the mean score for 2015 season (6.37 points ± 2.1 [5.83-6.92] 95% CI) was slightly lower, but not statistically different with a trivial effect than the score awarded in 2016 (6.51 points ± 2.06 [5.81-7.20] 95% CI) *d*=0.06.

It can be observed from figure 4a that there was a significant difference with a small effect R^2=0.028, *F*(5,1002)=5.856. *P*<0.0001 *d*=0.46 between scores awarded in 2014 (5.87 points ± 2.27 [5.58-6.17] 95% CI) for performing an aerial as the final manoeuvre, when compared with performing an aerial as a final manoeuvre in 2015 (6.83 points ± 1.74 [6.57-7.09] 95% CI). When we compared the scores for waves that ended with an aerial manoeuvre, the mean score for 2014 was almost one whole point lower than the score awarded in 2015. During the 2015 season, when an aerial was performed earlier in the

wave (6.59 points), they were also rewarded with a higher score than that in 2014 (6.47 points). The scores awarded in 2016 were identified to be lower than both 2014 and 2015.

******FIGURE FOUR HERE******

When we compared 2014 with the 2015 season a significant difference with a small to intermediate effect was indicated for the scores provided when aerials were performed in the first third of the heat (2014 season: 5.86 points ± 2.23 [5.40-6.32] 95% CI; 2015 season: 6.83 ± 1.79 [6.48-7.19] 95% CI) R^2=0.028, $F(8,999)=2.022$. P=0.0027 d=0.48. No other differences were observed in the score awarded within and between years, when compared to the timing of the heat. Scores awarded by the judges across the three time variables (Figure 4b) in 2015 were slightly higher.

DISCUSSION

This study aimed to investigate the influence on score awarded when including an aerial manoeuvre during competition. The inclusion of an aerial had a significant influence on the score awarded for the top two scoring waves across all three seasons (P<0.05), when compared to those waves which did not include an aerial manoeuvre (Figure 1). This difference of 0.80, 0.81 and 0.49 of a score in 2014, 2015 and 2016 respectively, was considered to have a small effect. Nevertheless, the difference between winning and losing a heat can be determined by a score as small as 0.01. The small, but significant differences can have a large impact on the surfers' ability to progress through a competition and improve their ranking as outlined by Farley and colleagues (2015). Farley et al (2015) found that the top 10 ranked surfers over the 2013 WCT season scored on average 1.04 more points per wave when compared to lower ranked surfers. Therefore, the inclusion of an aerial and the potential impact it has on scoring appears very important for bridging the gap between lower ranked surfers and the top 10 in elite level surfing athletes. Farley and associates (2015) further outlined that consistency and lower

variability within heat and individual wave score had a positive influence on competitive performance. Meaning that not only the inclusion of an aerial, but the successful performance of the manoeuvre may influence scoring potential.

When the surfer incorporated an aerial into competitive performance, the results of the current study are similar to earlier studies on scoring in competitive surfing by Lundgren and associates (2013; 2014). For the present study however, only the top two scoring waves for each surfer in each heat were analysed with regards to the overall impact of including an aerial manoeuvre during performance. This provided insights as to whether inclusion of an aerial into the performance positively influenced scoring potential, and the surfer's overall competitive performance. It is evident that during competition, both the inclusion and exclusion of an aerial manoeuvre are awarded a large range of scores (Figure 1). However, as previously outlined, the change in scoring criteria and the high risk associated with an aerial manoeuvre (Tesler, 2011) has enabled the judges to reward the surfer who incorporated an aerial in their wave riding repertoire. Therefore, the scoring potential when including an aerial manoeuvre during competitive performance has a positive impact on scoring potential (Lundgren et al., 2013, 2014; Souza et al., 2012; Piter, 2012).

Due to a vast amount of variables associated with surfing (wave formation, type of break, intensity, quality, environment etc.), waves are never the same and therefore, each wave has great influence in the variation and ability to perform manoeuvres and aerial manoeuvres (Lundgren et al, 2014; Peirão, & dos Santos, 2012). For the surfer to create the optimal velocity to leave the wave and perform an aerial manoeuvre, they need to perform the aerial within the steep part of the wave face, close to the pitching lip of the wave (Piter, 2012). This part of the wave is deemed the critical section of the wave, with judges looking for manoeuvres being as close to the pitching part of the wave to satisfy the judging criteria. However, with this steepness in the wave and the speed of the

breaking wave, performing manoeuvres in this part of the wave has been determined to be high risk for completion (Surfing Australia, 2014; International Surfing Association, 2015; World Surf League, 2017). Therefore, for the surfer to perform a highly complex manoeuvre, such as an aerial in a critical part of the wave, the successful completion of a high risk aerial manoeuvre fulfils the judges scoring criteria and results in the surfer being rewarded with a higher score.

From the results (Figure 2a) it can be identified that the ability of the surfer to complete an aerial manoeuvre during both the 2014 and 2015 seasons is below 55%. This completion rate is somewhat lower compared to the completion rates of turning manoeuvres, which were found to be above 90% (Lundgren et al., 2014; Souza et al., 2012). This result may indicate that when the surfer performs and completes an aerial manoeuvre, the surfer is rewarded by the judges with a higher score (Figure 1), whilst potentially increasing the chances of that wave counting as one of the surfer's top two scoring waves. An interesting observation made during analysing the 2016 season was that both the straight air (67%) and alley oop (70%) improved markedly in completion rate from the previous two seasons (Figure 2a). Further analysis revealed that 50% of the straight air attempts (6 aerials) were counted within the surfers' top two scoring waves (12 attempts). This information indicates that when the surfer performed this manoeuvre successfully the aerial was possibly rewarded by the judges. This can be further supported by the single Alley Oop with a grab that was successfully performed in 2016. This aerial variation was positively rewarded by the judges with a score of 7.83, which was 1.08 points higher than the score provided for those performing the same aerial variation without a grab (n=21 mean=6.75 points) in the same year. However, future studies focussed on judging and award of score would need to be carried out to verify this.

With reference to the difference in variations of aerial types and score awarded there was found to be a significant difference in the scores awarded between seasons for both the

air reverse and full rotation (Figure 2b). Analysis reveals the air reverse variation is the most common form of aerial attempted in competition (Figure 2a) with 2015 being the year that judges rewarded the surfer with higher scores than in both 2014 (0.74 of a point) and 2016 (0.55 of a point). Of the eight other variations, the full rotation which requires a full 360^0 rotation as opposed to the 180^0 rotation seen in the air reverse was the only other variation that provided significant results. When comparing the 2014 and 2015 seasons for the full rotation (Figure 2b), the score provided in 2015 was 1.3 points higher than 2014 (P=0.0177).

Forsyth et al. (2017) suggested that during the final series of the 2015 season, the forehand straight and forehand full rotation were awarded higher scores than the forehand air reverse. However, with the current study and that carried out by Forsyth and associates (2017), aspects such as other manoeuvres performed on the wave, orientation and axis of rotation of the aerial (technical aspects) have not been quantified. These components all impact on the overall wave performance and aesthetics of the aerial manoeuvre. But when considering the 5 key elements of scoring and the inclusion of aerial manoeuvres, judges need to consider the additional 180^0 rotation within the context of the criteria. By increasing the technical ability of the surfer, this may enable the surfer to add a further dimension to the variation performed increasing their scoring potential. This additional complexity above the lip of the wave also addresses the key judging components of difficulty, commitment, innovation and progression.

The direction the surfer faced during the wave ride also indicated a seasonal effect with regards to scoring potential. During the 2015 season, the score awarded for aerials performed on the forehand (facing the wave face) were awarded a significantly (P=0.0113) greater score than those in 2016 (Figure 3). No difference was seen in the score awarded when the surfer performed an aerial on their backhand for either the 2015 and 2016 seasons or when compared to performing an aerial on the forehand. However,

further analysis by Forsyth and associates (2017) during the final series identified for the air reverse manoeuvre in 2015, the backhand attempts were awarded a higher score than forehand attempts. Although this and previous results related to forehand aerials by Forsyth and colleagues (2017) do show a trend in scoring potential, these scores awarded were not significantly different and did not look at the performance leading up to the finals. Furthermore, we cannot make broad based conslusions about the meaningfulness of forehand and backhand aerials and scoring potential, due to methodological reasons that we were not able to overcome. In surfing, a backhand aerial is more difficult for the vast majority of participants, suggesting that this should feature higher in the judging criteria. However, this may also suggest that the forehand airs are better (bigger flight height and time, greater control and grab execution, more dynamic rotation), because the surfers are able to gain better speed and be more precise in their execution.

When the surfer performed the aerial manoeuvre as the final move on the wave, it was awarded a greater score ($P<0.0001$) in the 2015 season (Figure 4a) than when surfers successfully performed an aerial as a final move in 2014 (0.955 of a point difference). However, within seasons there does not seem to be an effect with regards to order of performance of an aerial manoeuvre. Within a coaching aspect choosing to perform a higher risk manoeuvre like an aerial, earlier in the sequence of manoeuvres, does increase the risk of not completing the wave, which would result in a score so low it would likely not factor into the top two scores in order to win a heat. As such, this risk is associated with a higher reward. However, our finding must be interpreted in the broader context of wave selection and manoeuvre selection. We suggest that performing an aerial as a first manoeuvre is risky, and is rewarded, but that on average, surfers are more likely to attempt an aerial as a first manoeuvre on waves that do not offer an overall high scoring potential (e.g. a close-out or a generally poor wave). Put simply, we suggest it is not the

selection of the aerial early in the ride, but that aerials are being performed early in the ride on waves that do not have a very high scoring potential in the first place.

This effect can only be theorised if the aerial performed to finish the wave is deemed to be more influential than the rest of the manoeuvres performed on the wave previously. When assessing the key variables for a successful performance of an aerial; speed, height and acrobatic ability and landing (Lundgren et al., 2013; Ferrier et al., 2014), the section of the wave for the performance of this final manoeuvre would then need to be accommodating enough for the surfer to perform the aerial on. But anecdotally, for the surfer to produce the sufficient speed required for the take-off of an aerial manoeuvre, they would then miss prior opportunities for performing other manoeuvres, thus missing potential scoring opportunities and addressing the judging criteria of combination and variety of manoeuvres. This order of performance and where the aerial is placed in the sequence does seem to be an important aspect in the judging criteria and the performance. However, size of the section of the wave the aerial was performed on and number of previous manoeuvres prior to the aerial would be required to get a better understanding of the impact order and its impact on scoring potential.

In regards to time segment within the heat that the aerial manoeuvre was performed, the results were that the only significant difference in score awarded (P=0.041) was between the 2014 and 2015 seasons in the first third of the heat (Figure 4b). Plessner and Haar (2006) outlined that judges tend to use recall from previous scoring opportunities to base their scoring decision upon. Therefore, if judges utilise previous performances for scoring potential, a bias can then become evident, as there is potential for the judge to base the score from memory, and not the performance on its own merits. However, further research into judging and associated scoring is needed.

This finding has implications for the performing surfer and strategies within a heat. If the surfer strategically attempts to incorporate an aerial later in the heat, thinking it will influence the judges, the results show that this is a dangerous strategy to undertake. The findings instead indicate that a surfer should take the opportunity to perform an aerial when, and if, the wave allows the opportunity, with no real bias toward parts of a heat in relation to judging bias or creating a last ditch attempt to sway the judges. This along with where the aerial was performed in the wave sequence would further enhance performance and understanding of influence on score. If the surfer performed multiple manoeuvres and performed the aerial early in the sequence, landing spots like the bottom or the face of the wave would theoretically better enable the surfer to connect additional manoeuvres without losing too much speed or flow. But if they landed effectively in the other areas of the wave, this would mean the surfer would need to negotiate turbulence (white water) or the drop from the top of the wave to then connect to the next part of the wave. Therefore, the importance of the landing spot and the order of the aerial on the wave needs to be better understood to enable the surfer and coach a deeper understanding of the scoring potential.

PRACTICAL APPLICATION

This study highlights the importance of the inclusion of an aerial manoeuvre in a competitive surfing repetoire and further explains the impact of an aerial on scoring with regards to variation, completion rate, timing and the direction the surfer is facing when performing the aerial manoeuvre. We encourage surfers and coaches to endeavour to incorporate aerial manoeuvres, especially those that comply with the judging criteria. Therefore, those manoeuvres that require a high technical proficiency such as full rotations and alley oop’s on both the forehand and backhand have a tendency to be positively rewarded. Therefore, physical preparation and a skills based practice related to

the performance of this manoeuvre in surfing is important to maximise competitive performance. Especially when incorporating the more technically advanced variations such as the full rotation and alley oop variation.

With regards to timing of the manoeuvre, there is no reward seen over the three years with regards to strategy of inclusion of the manoeuvre. Therefore, we encourage the athlete to perform aerial manoeuvres when the wave dynamics allow the manoeuvre to be performed. As strategically incorporating an aerial manoeuvre late in the context of the heat may not be rewarded positively.

CONCLUSION

The results of the present study, in combination with earlier studies by Lundgren et al. (2013; 2014); Peirão and dos Santos (2012), Forsyth et al. (2017) and Ferrier et al. (2014) have all indicated that when a surfer incorporates an aerial into their performance, they will be rewarded with a higher score. When a surfer includes an aerial manoeuvre, our findings suggest the more technical variations such as an aerial reverse and full rotation are rewarded a higher score by the judges. With regards to heat strategy, results suggest there is no benefit to timing an aerial manoeuvre within the heat, or order of performance within a wave. But results do suggest that those aerials performed on the forehand are positively rewarded by the judging panel. Therefore, the authors suggest that a better understanding of the technical aspects to successfully perform an aerial manoeuvre are required to further assess the advent of this manoeuvre and its impact on the competitive aspect of surfing. It is clear however from the findings of this study and previous studies that a surfer's ability to perform an aerial continues to have a positive impact on competitive performance and the athlete's ability to score.

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Table One: Aerial Variation Classification and Definition

Aerial Variation	Definition
Straight	Where the board and rider are projected above the lip line of the wave with no rotation
Straight with Grab	As above, however the surfer grabs the rail of the board whilst in the air
Air Reverse	Where the rider and board rotate forward at least 180 degrees whilst in the air, before landing backwards
Air Reverse with Grab	As above, however the surfer grabs to rail of the board during the rotation
Full Rotation	Where the rider and board rotate forward at least 360 degrees whilst in the air, before landing
Full Rotation with Grab	As above, however the surfer grabs to rail of the board during the rotation
Alley Oop	Where the rider and board rotates backwards at least 180 degrees whilst in the air before landing back on the wave
Alley Oop with Grab	As above, however the surfer grabs to rail of the board during the rotation
Other	Any other variation of aerial variation that incorporates a variety of spins off axis or combination of grabs or rotations that do not fit into the above classifications.

Piter (2012)

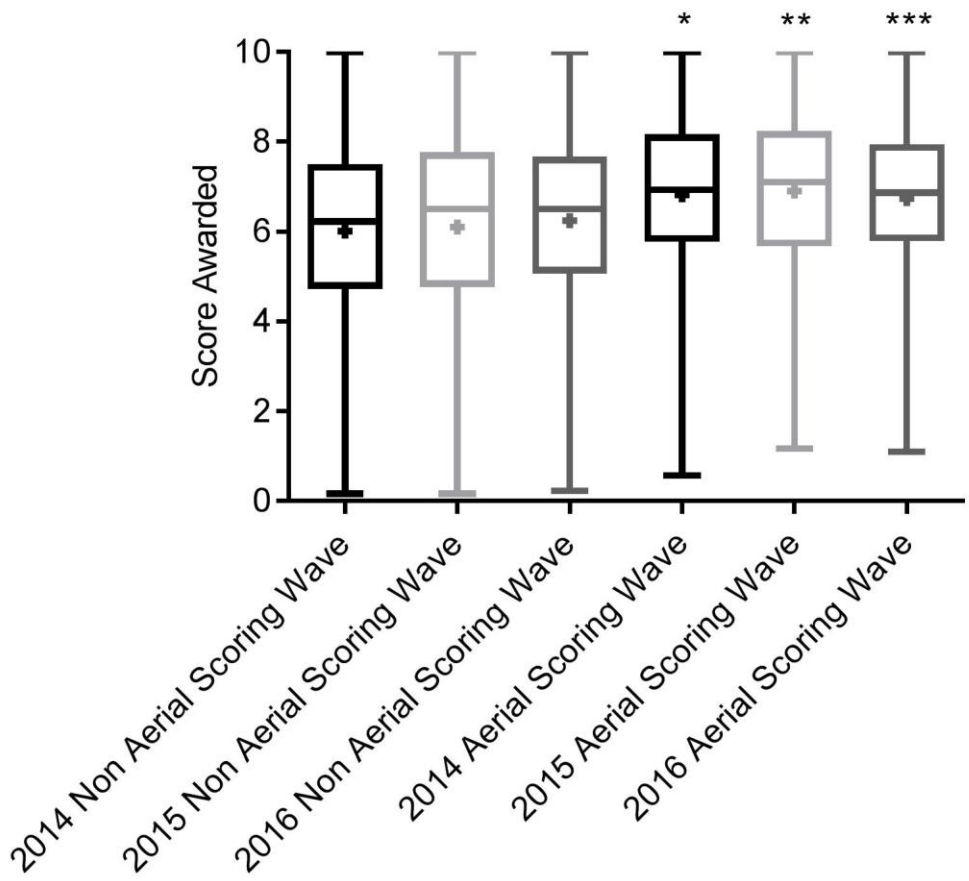


Figure One: Box and whisker plot of comparison of scores awarded to waves which counted as the top two wave scores that included an aerial compared to waves that did not include an aerial during the 2014, 2015 and 2016 WSL competitive season. Centre Line = median, top of box =75th percentile, bottom of box = 25th percentile, whiskers = data within the range of minimum and maximum score awarded, + = mean. * = significant difference ($p<0.0001$) between 2014 Non Aerial Scoring Wave and 2014 Aerial Scoring Wave. ** = significant difference ($p<0.0001$) between 2015 Non Aerial Scoring Wave and 2015 Aerial Scoring Wave. *** = significant difference ($p=0.0066$) between 2016 Non Aerial Scoring Wave and 2016 Aerial Scoring Wave.

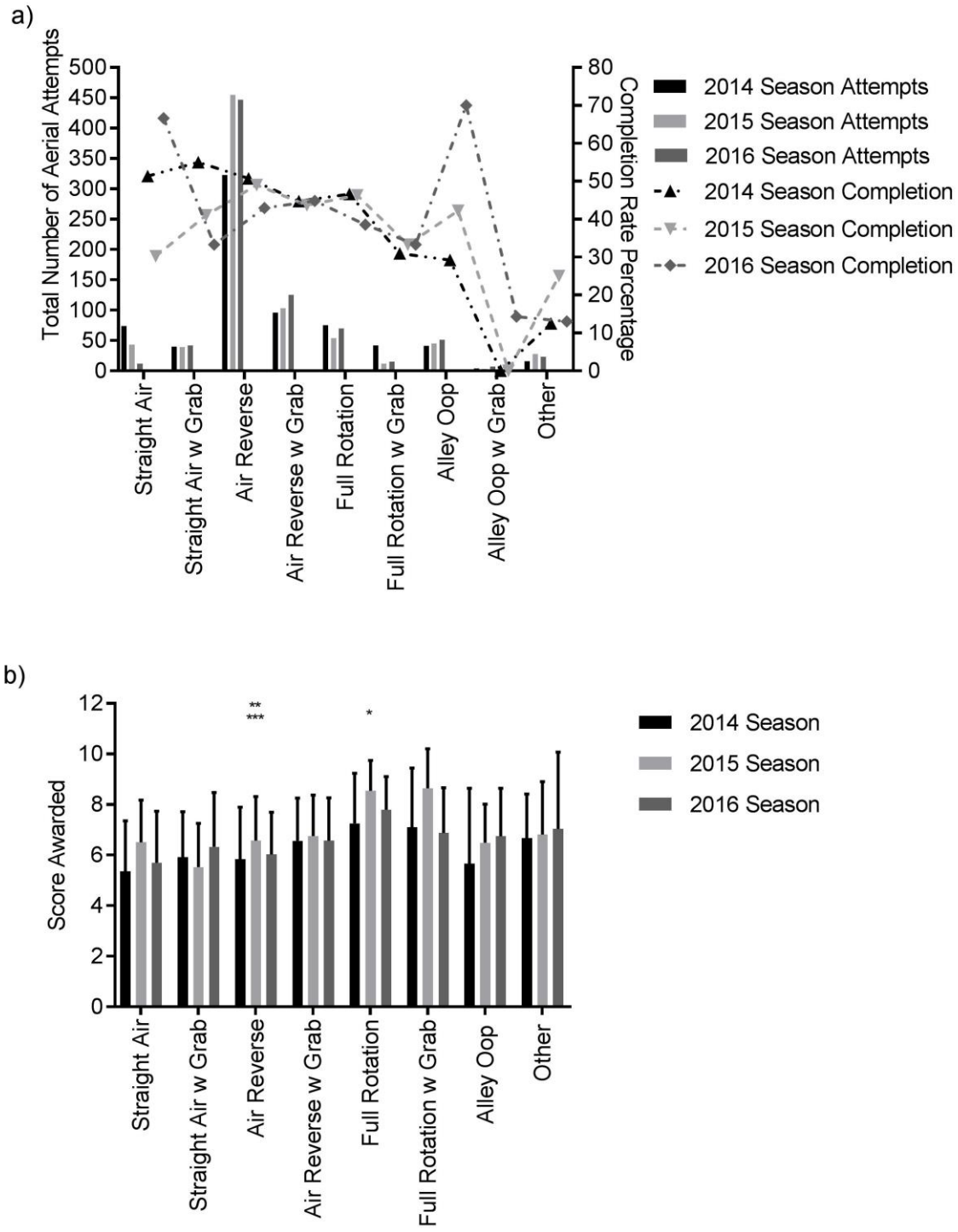


Figure Two: Comparison of aerial variations performed during the 2014, 2015 and 2016 WSL seasons. (a) Descriptive statistics of total number of aerial attempts and the overall completion rate of these attempts and (b) Mean and standard deviation of the scores awarded for the successful completion of 8 aerial variations. * = significant difference (p=0.0177) between the score awarded for the 2014 Full Rotation Aerial and 2015 Full Rotation Aerial. ** = significant difference (p=0.0002) between the score awarded

for the 2014 Air Reverse and 2015 Air Reverse. *** = significant difference (p=0.0057) between the score awarded for the 2015 Air Reverse and 2016 Air Reverse.

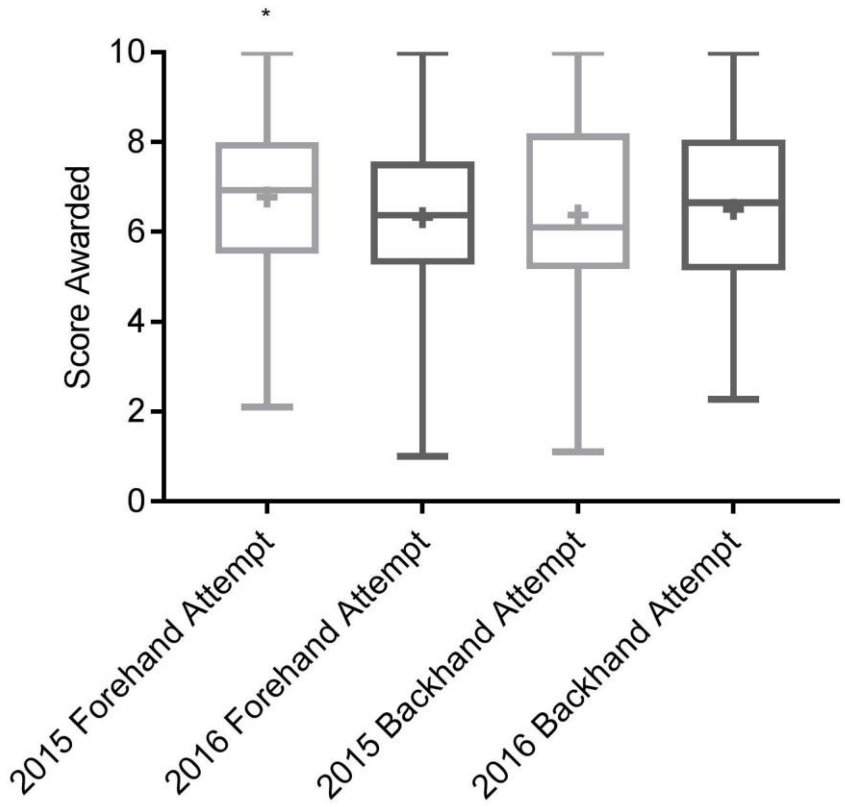
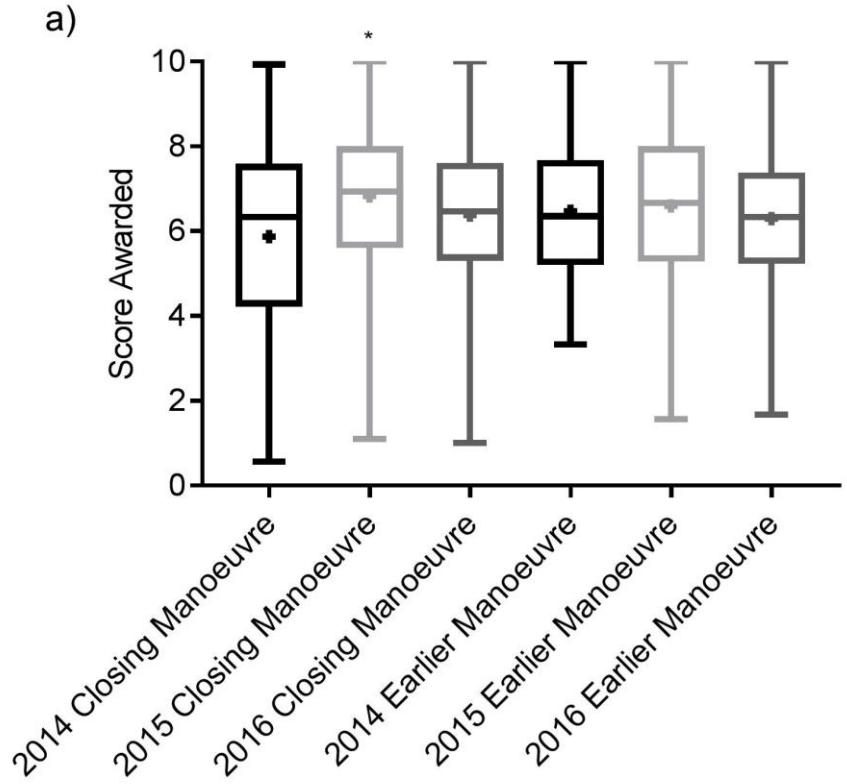


Figure Three: Box and whisker plot of temporal aspects related to the direction the surfer was facing on the wave when the aerial manoeuvre was performed. Centre Line = median, top of box =75th percentile, bottom of box = 25th percentile, whiskers = data within the range of minimum and maximum score awarded, + = mean. * = significant difference in score awarded with 2016 forehand attempt (p=0.0113).


a)
*
Score Awarded
10
8
6
4
2
0
2014 Closing Manoeuvre
2015 Closing Manoeuvre
2016 Closing Manoeuvre
2014 Earlier Manoeuvre
2015 Earlier Manoeuvre
2016 Earlier Manoeuvre

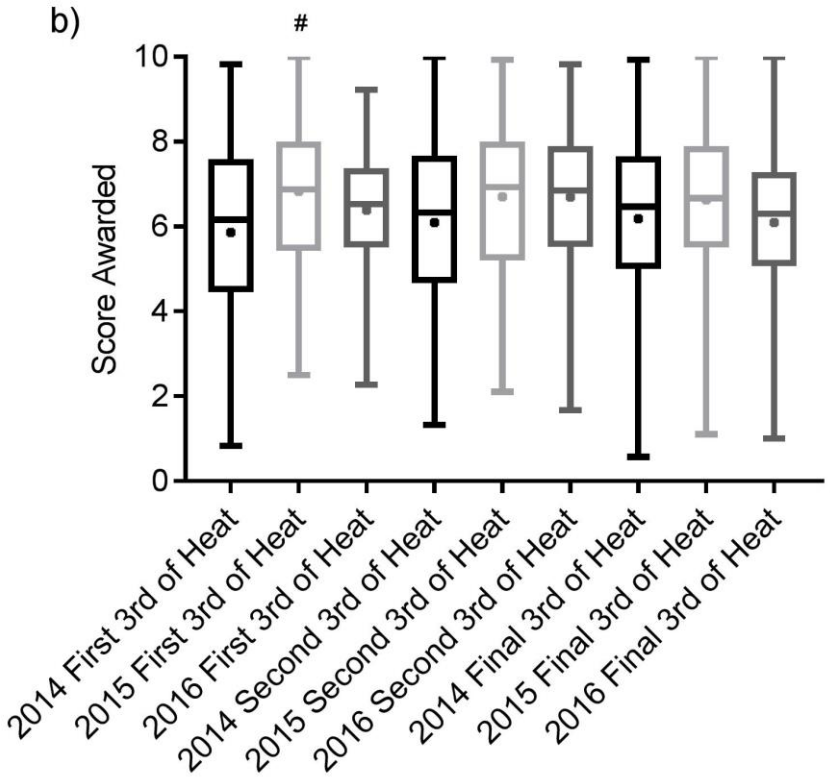

b)
#
Score Awarded
10
8
6
4
2
0
2014 First 3rd of Heat
2015 First 3rd of Heat
2016 First 3rd of Heat
2014 Second 3rd of Heat
2015 Second 3rd of Heat
2016 Second 3rd of Heat
2014 Final 3rd of Heat
2015 Final 3rd of Heat
2016 Final 3rd of Heat

Figure Four: Box and whisker plot of temporal aspects related to when the aerial manoeuvre was performed. (a) Comparison of scores when the aerial manoeuvre was performed as the last move on the wave with performance of the aerial earlier in the sequence of manoeuvres. (b) Comparison of scores awarded for the wave when it was performed in the 1st, 2nd or 3rd time interval of the heat. Centre Line = median, top of box =75th percentile, bottom of box = 25th percentile, whiskers = data within the range of minimum and maximum score awarded, + = mean. * = significant difference ($p<0.0001$) in score awarded for 2014 Closing Manoeuvre and 2015 Closing Manoeuvre. # = significant difference ($p=0.0027$) in score awarded for the inclusion of an aerial in the first third of the heat in 2014 and the score awarded for the inclusion of an aerial in the first third of the heat in 2015.

Scoring Analysis of the Men's 2014, 2015 and 2016 World Championship Tour of Surfing: The Importance of Aerial Manoeuvres in Competitive Surfing.

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ABSTRACT

The aim of this study was to investigate the impact of aerial manoeuvres on scoring in professional surfing. 23631 waves were analysed for the number and types of aerial manoeuvres performed from the 2014, 2015 and 2016 Men's World Championship Tour. Additionally, the awarded score, timing and order of the aerial was also analysed. Descriptive statistics and Two Way ANOVA's were performed with Sidak Multiple Comparisons Post Hoc analysis. Results were a significantly higher score being awarded ($P \leq 0.0001$) when including an aerial in competition across all three seasons. In 2015 surfers were awarded a significantly larger score when performing an air reverse, compared to 2014 ($P=0.0002$) and 2016 ($P=0.0057$). Surfers were also awarded a higher score for the full rotation aerial in 2015 compared to 2014 ($P=0.0177$). In 2015 surfers performing forehand aerials were awarded a greater score than in 2016 ($P=0.0113$). The timing of the aerial and score awarded was significantly greater in 2015 as opposed to 2014 when the aerial was their final manoeuvre ($P<0.0001$) and when surfers timed the aerial performance early within the heat ($P=0.0027$). If a surfer incorporates an aerial manoeuvre during competition, generally speaking, they will be awarded a significantly higher score.

Keywords: Notational Analysis, Performance, Awarded Score, Coaching Impact

INTRODUCTION

In competitive surfing, the athlete's performance on each wave surfed is subjectively assessed on a scale of 0-10 points by a panel of 5 accredited judges. The judge's score is based on five key elements: 1) commitment and degree of difficulty; 2) innovative and progressive manoeuvres; 3) combination of major manoeuvres; 4) variety of manoeuvres; and 5) speed, power and flow (World Surf League [WSL], 2014). For a surfer's performance to be awarded a higher score, a combination of manoeuvres that address the 5 key elements in the most critical sections of the wave must be performed (Lundgren, Dunn, Nimphius, & Sheppard, 2013; Lundgren, Newton, Tran, Dunn, Nimphius, S, & Sheppard, 2014). The surfer with the highest two-wave total is deemed the winner of the heat. One of the most highly regarded manoeuvres in competitive surfing that has been linked with high performance and high risk is the aerial (Lundgren et al., 2014). The aerial manoeuvre incorporates the surfer launching themselves above the top of the wave then landing back on the same wave to continue their ride (Ferrier, Sheppard, Newton, & Nimphius, 2014).

The importance of the inclusion of an aerial manoeuvre was highlighted previously by Peirão and dos Santos (2012) during two Association of Surfing Professionals (ASP) competitions in 2007 and 2010. The study reported that the performance of an aerial manoeuvre when incorporated with a series of other manoeuvres had a low but significant correlation (r = 0.30; $P \leq 0.001$) with wave score. Additionally, our research team (Lundgren et al., 2014) also reported that surfers including an aerial manoeuvre during competitions were awarded an average score of 7.40 (±1.53) out of 10. In comparison, the same study highlighted that rides not including an aerial were on average, awarded a significantly lower (P<0.001) score of 5.08 (±2.21) during the 2012 ASP World Championship Tour. A recent study by Forsyth, de la Harpe, Riddiford-Harland,

Whitting, & Steele (2017) agreed with both previous studies reporting that during the 2015 World Championship Tour (WCT), surfers who included an aerial manoeuvre were awarded a significantly greater score than when they just performed manoeuvres on the wave face.

An interesting observation from the earlier study by Lundgren and associates (2014) was the aerial completion rate during competition. The authors highlighted that during competition, the completion rate of an aerial in competition was below 50% (Lundgren et al., 2014) outlining that it may be deemed a high risk manoeuvre to perform. Even with this low success rate, the three highlighted studies indicate that the inclusion of an aerial may still have a major influence on scoring potential. Tesler (2011) suggested that when a surfer includes an aerial manoeuvre whilst performing in competition, there is an inherent risk of either a wipe out or incomplete ride, thereby resulting in a lower score for that wave. However, with the recent changes to the scoring criteria, the risk and athleticism required to perform an aerial manoeuvre pairs itself well in the competitive situation, creating a risk-reward status for the surfer and their wave score when including an aerial manoeuvre. Recently, it has been observed within competition that the performance of an aerial alone (i.e. no other manoeuvres on that wave) can be deemed by the judges to address all the components of the judging criteria, and can be awarded the maximum 10 available points (Tesler, 2011).

Earlier, it was outlined by Farley, Raymond, Secomb, Ferrier, Lundgren, Tran, Abbiss, & Sheppard (2015) that the majority of studies in performance surfing have mainly focused on the physiological requirements (Farley, Harris, & Kilding, 2012), anthropometric variables (Barlow, Findlay, Gresty, & Cooke, 2014) and paddling performance (Sheppard, Osborne, Chapman, & Andrews, 2012) of elite level surfers. Such research has made major inroads into understanding the fitness requirements and physical attributes required for elite level competitive surfing. However, so far there is

limited published research regarding performance analysis in international competition and how the surfers choice of manoeuvre can influence scoring potential (Ferrier et al., 2014; Forsyth et al., 2017; Lundgren et al., 2013, 2014; Peirão and dos Santos, 2012).

Therefore, the aim of the current study was to investigate whether the inclusion of an aerial manoeuvre during competition continues to have a positive impact on scoring potential and whether this trend is evolving. The researchers sought to further investigate if the effect of aerial variation, order of manoeuvre during the surfing performance and timing of the aerial manoeuvre during the overall heat had an influence on competitive performance and scoring potential during the 2014, 2015 and 2016 Men's WCT. The findings of this study have potential to provide an insight into the effectiveness of including aerial manoeuvres in the wave riding repertoire, and whether the inclusion of an aerial manoeuvre and when it is performed during competition positively impacts the score awarded.

METHODS

All data were recorded for the 33 events carried out during the 2014 (n=11), 2015 (n=11) and 2016 (n=11) Men's WCT, where all waves (n=23631) surfed were analysed. Data collection was carried out between the months February 2014 through February 2017 from on-line video content available from the respective events heat analyser function available on the World Surf League website (WSL, 2014). The study and procedures were approved by Edith Cowan University Human Ethics Committee (approval number: 10320).

For each wave surfed, the number of manoeuvres were counted and further categorised as either including an aerial (n=2285) or non-aerial (n=21346). An aerial manoeuvre was classified as when the whole board and athlete's body was clear from the top of the wave, with the athlete's board and body in the air (Ferrier et al., 2014). This did not include a

free fall from a previous manoeuvre. The score awarded for all waves, as well as the awarded score for the waves counted as the surfer's top two scoring waves were noted from the World Surf League website (2014). The waves including a completed aerial attempt were then classified into 9 variations (Table One), with the order the aerial was performed on the wave also recorded. Each heat was divided into 3 equal time segments as heat times can range from 30 minutes to 40 minutes within a competition. This allowed for the calculation of temporal characteristics when each wave including an aerial manoeuvre was performed. Subsequently this allowed the authors to identify if the timing of the wave within the heat, including the aerial attempt, had an influence on scoring potential. In addition, for the 2015 and 2016 seasons, the surfers performance of the aerial was recorded and categorised to either forehand (surfer facing the wave when riding) or backhand (surfers back to the wave when riding) to investigate if the stance had an impact on the score awarded.

*******Table One Here*******

Statistical Analysis

Standard descriptive statistics of mean and standard deviations were calculated. A one-way repeated measures ANOVA was performed to determine significance of difference between aerial score, timing of aerial performance and direction the surfer was facing when the aerial was completed with the year of competition. A within variation two-way ANOVA was carried out to compare the differences in score awarded between years for each aerial variation performed. All data was assessed for normality using a D'Agostino test. In the event of the assumption of normality being violated the Greenhouse-Geisser correction adjustment was used. Where a significant difference was indicated a Sidak Multiple Comparisons Post Hoc Test was used to identify individual statistical variances. The magnitude of differences was evaluated by calculating effect sizes (Cohens *d*).

Magnitude of effect was based on the following criteria: >0.2, trivial; 0.2-0.5, small; 0.5-0.8, medium; and >0.8, large (Cohen, 1988). All statistical analyses were carried out using GraphPad Prism version 7.02 for Windows (GraphPad Software, LaJolla California USA, www.graphpad.com) with statistical significance being set at $P \leq 0.05$.

RESULTS

As outlined in Figure 1, there was a significant difference between the mean scores of the wave rides that incorporated an aerial manoeuvre (6.82, 6.91, 6.74), versus waves without an aerial (6.01, 6.10, 6.25) in the 2014, 2015 and 2016 seasons respectively R^2=0.012, $F(5,7690)=16.86$, $P<=0.0001$. Of the 2285 waves analysed that included an aerial, 711 aerials were attempted in 2014, 782 were attempted in 2015 and 792 were attempted in 2016. The most common variation of aerial attempted over the three years was the air reverse with 323 attempts in 2014, 455 attempts in 2015 and 447 attempts in 2016 (Figure 2a).

******FIGURE ONE HERE******

The completion rate of the air reverse aerial variation was 51% during the 2014 competitive season, 49% in 2015 and 43% in 2016. The aerial variation with the highest completion rate in 2014 was the straight air with a grab (55%), and in 2015 it was the air reverse (49%). During the 2016 season, the alley oop was the most successful variation with a completion rate of 70%. The variation with the least attempts across all years was the alley oop with grab (4 attempts in 2014, 3 attempts in 2015 and 7 attempts in 2016) with a 0% completion rate for both 2014 and 2015, and a single completion in 2016 (see Figure 2a).

******FIGURE TWO HERE******

The two way ANOVA indicated a significant and small effect difference R^2=0.5855, F(2,982)=3.028 in the score awarded between the 2014 (5.83 points ± 2.06 [5.52-6.15] 95% CI) vs 2015 (6.58 points ± 1.74 [6.35-6.81] 95% CI) (P=0.0002, d=0.39) and 2015 (6.58 points ± 1.74 [6.35-6.81] 95% CI) vs 2016 (6.02 points ± 1.67 [5.79-6.26] 95% CI), (P=0.006, d=0.32) seasons for the air reverse variation of aerials (Figure 2b). It is further indicated in figure 2b, when the surfer included a full rotation aerial during the 2015 season (8.55 points ± 1.20 [8.05-9.04] 95% CI), they received a significant and moderate increase in score (P=0.018, d=0.76) as opposed to performing the same aerial in 2014 (7.11 points ± 2.34 [5.69-8.52] 95% CI).

******FIGURE THREE HERE******

When the surfer performed an aerial on their forehand they were rewarded with a significant and small effect increase in score during 2015 (6.78 points ± 1.69 [6.59-6.98] 95% CI) than in 2016 (6.32 points ± 1.73 [6.12-6.52] 95% CI) R^2=0.015, F(3,675)=3.426. P=0.011, d=0.27. As indicated in figure 3, when comparing the scores for waves performed on the backhand the mean score for 2015 season (6.37 points ± 2.1 [5.83-6.92] 95% CI) was slightly lower, but not statistically different with a trivial effect than the score awarded in 2016 (6.51 points ± 2.06 [5.81-7.20] 95% CI) d=0.06.

It can be observed from figure 4a that there was a significant difference with a small effect R^2=0.028, F(5,1002)=5.856. P<0.0001 d=0.46 between scores awarded in 2014 (5.87 points ± 2.27 [5.58-6.17] 95% CI) for performing an aerial as the final manoeuvre, when compared with performing an aerial as a final manoeuvre in 2015 (6.83 points ± 1.74 [6.57-7.09] 95% CI). When we compared the scores for waves that ended with an aerial manoeuvre, the mean score for 2014 was almost one whole point lower than the score awarded in 2015. During the 2015 season, when an aerial was performed earlier in the

wave (6.59 points), they were also rewarded with a higher score than that in 2014 (6.47 points). The scores awarded in 2016 were identified to be lower than both 2014 and 2015.

******FIGURE FOUR HERE******

When we compared 2014 with the 2015 season a significant difference with a small to intermediate effect was indicated for the scores provided when aerials were performed in the first third of the heat (2014 season: 5.86 points ± 2.23 [5.40-6.32] 95% CI; 2015 season: 6.83 ± 1.79 [6.48-7.19] 95% CI) R^2=0.028, F(8,999)=2.022. P=0.0027 d=0.48. No other differences were observed in the score awarded within and between years, when compared to the timing of the heat. Scores awarded by the judges across the three time variables (Figure 4b) in 2015 were slightly higher.

DISCUSSION

This study aimed to investigate the influence on score awarded when including an aerial manoeuvre during competition. The inclusion of an aerial had a significant influence on the score awarded for the top two scoring waves across all three seasons (P<0.05), when compared to those waves which did not include an aerial manoeuvre (Figure 1). This difference of 0.80, 0.81 and 0.49 of a score in 2014, 2015 and 2016 respectively, was considered to have a small effect. Nevertheless, the difference between winning and losing a heat can be determined by a score as small as 0.01. The small, but significant differences can have a large impact on the surfers' ability to progress through a competition and improve their ranking as outlined by Farley and colleagues (2015). Farley et al (2015) found that the top 10 ranked surfers over the 2013 WCT season scored on average 1.04 more points per wave when compared to lower ranked surfers. Therefore, the inclusion of an aerial and the potential impact it has on scoring appears very important for bridging the gap between lower ranked surfers and the top 10 in elite level surfing athletes. Farley and associates (2015) further outlined that consistency and lower

variability within heat and individual wave score had a positive influence on competitive performance. Meaning that not only the inclusion of an aerial, but the successful performance of the manoeuvre may influence scoring potential.

When the surfer incorporated an aerial into competitive performance, the results of the current study are similar to earlier studies on scoring in competitive surfing by Lundgren and associates (2013; 2014). For the present study however, only the top two scoring waves for each surfer in each heat were analysed with regards to the overall impact of including an aerial manoeuvre during performance. This provided insights as to whether inclusion of an aerial into the performance positively influenced scoring potential, and the surfer's overall competitive performance. It is evident that during competition, both the inclusion and exclusion of an aerial manoeuvre are awarded a large range of scores (Figure 1). However, as previously outlined, the change in scoring criteria and the high risk associated with an aerial manoeuvre (Tesler, 2011) has enabled the judges to reward the surfer who incorporated an aerial in their wave riding repertoire. Therefore, the scoring potential when including an aerial manoeuvre during competitive performance has a positive impact on scoring potential (Lundgren et al., 2013, 2014; Souza et al., 2012; Piter, 2012).

Due to a vast amount of variables associated with surfing (wave formation, type of break, intensity, quality, environment etc.), waves are never the same and therefore, each wave has great influence in the variation and ability to perform manoeuvres and aerial manoeuvres (Lundgren et al, 2014; Peirão, & dos Santos, 2012). For the surfer to create the optimal velocity to leave the wave and perform an aerial manoeuvre, they need to perform the aerial within the steep part of the wave face, close to the pitching lip of the wave (Piter, 2012). This part of the wave is deemed the critical section of the wave, with judges looking for manoeuvres being as close to the pitching part of the wave to satisfy the judging criteria. However, with this steepness in the wave and the speed of the

breaking wave, performing manoeuvres in this part of the wave has been determined to be high risk for completion (Surfing Australia, 2014; International Surfing Association, 2015; World Surf League, 2017). Therefore, for the surfer to perform a highly complex manoeuvre, such as an aerial in a critical part of the wave, the successful completion of a high risk aerial manoeuvre fulfils the judges scoring criteria and results in the surfer being rewarded with a higher score.

From the results (Figure 2a) it can be identified that the ability of the surfer to complete an aerial manoeuvre during both the 2014 and 2015 seasons is below 55%. This completion rate is somewhat lower compared to the completion rates of turning manoeuvres, which were found to be above 90% (Lundgren et al., 2014; Souza et al., 2012). This result may indicate that when the surfer performs and completes an aerial manoeuvre, the surfer is rewarded by the judges with a higher score (Figure 1), whilst potentially increasing the chances of that wave counting as one of the surfer's top two scoring waves. An interesting observation made during analysing the 2016 season was that both the straight air (67%) and alley oop (70%) improved markedly in completion rate from the previous two seasons (Figure 2a). Further analysis revealed that 50% of the straight air attempts (6 aerials) were counted within the surfers' top two scoring waves (12 attempts). This information indicates that when the surfer performed this manoeuvre successfully the aerial was possibly rewarded by the judges. This can be further supported by the single Alley Oop with a grab that was successfully performed in 2016. This aerial variation was positively rewarded by the judges with a score of 7.83, which was 1.08 points higher than the score provided for those performing the same aerial variation without a grab (n=21 mean=6.75 points) in the same year. However, future studies focussed on judging and award of score would need to be carried out to verify this.

With reference to the difference in variations of aerial types and score awarded there was found to be a significant difference in the scores awarded between seasons for both the

air reverse and full rotation (Figure 2b). Analysis reveals the air reverse variation is the most common form of aerial attempted in competition (Figure 2a) with 2015 being the year that judges rewarded the surfer with higher scores than in both 2014 (0.74 of a point) and 2016 (0.55 of a point). Of the eight other variations, the full rotation which requires a full 360^0 rotation as opposed to the 180^0 rotation seen in the air reverse was the only other variation that provided significant results. When comparing the 2014 and 2015 seasons for the full rotation (Figure 2b), the score provided in 2015 was 1.3 points higher than 2014 (P=0.0177).

Forsyth et al. (2017) suggested that during the final series of the 2015 season, the forehand straight and forehand full rotation were awarded higher scores than the forehand air reverse. However, with the current study and that carried out by Forsyth and associates (2017), aspects such as other manoeuvres performed on the wave, orientation and axis of rotation of the aerial (technical aspects) have not been quantified. These components all impact on the overall wave performance and aesthetics of the aerial manoeuvre. But when considering the 5 key elements of scoring and the inclusion of aerial manoeuvres, judges need to consider the additional 180^0 rotation within the context of the criteria. By increasing the technical ability of the surfer, this may enable the surfer to add a further dimension to the variation performed increasing their scoring potential. This additional complexity above the lip of the wave also addresses the key judging components of difficulty, commitment, innovation and progression.

The direction the surfer faced during the wave ride also indicated a seasonal effect with regards to scoring potential. During the 2015 season, the score awarded for aerials performed on the forehand (facing the wave face) were awarded a significantly (P=0.0113) greater score than those in 2016 (Figure 3). No difference was seen in the score awarded when the surfer performed an aerial on their backhand for either the 2015 and 2016 seasons or when compared to performing an aerial on the forehand. However,

284 further analysis by Forsyth and associates (2017) during the final series identified for the
285 air reverse manoeuvre in 2015, the backhand attempts were awarded a higher score than
286 forehand attempts. Although this and previous results related to forehand aerials by
287 Forsyth and colleagues (2017) do show a trend in scoring potential, these scores awarded
288 were not significantly different and did not look at the performance leading up to the
289 finals. Furthermore, we cannot make broad based conslusions about the meaningfulness
290 of forehand and backhand aerials and scoring potential, due to methodological reasons
291 that we were not able to overcome. In surfing, a backhand aerial is more difficult for the
292 vast majority of participants, suggesting that this should feature higher in the judging
293 criteria. However, this may also suggest that the forehand airs are better (bigger flight
294 height and time, greater control and grab execution, more dynamic rotation), because the
295 surfers are able to gain better speed and be more precise in their execution.

296 When the surfer performed the aerial manoeuvre as the final move on the wave, it was
297 awarded a greater score ($P<0.0001$) in the 2015 season (Figure 4a) than when surfers
298 successfully performed an aerial as a final move in 2014 (0.955 of a point difference).
299 However, within seasons there does not seem to be an effect with regards to order of
300 performance of an aerial manoeuvre. Within a coaching aspect choosing to perform a
301 higher risk manoeuvre like an aerial, earlier in the sequence of manoeuvres, does increase
302 the risk of not completing the wave, which would result in a score so low it would likely
303 not factor into the top two scores in order to win a heat. As such, this risk is associated
304 with a higher reward. However, our finding must be interpreted in the broader context of
305 wave selection and manoeuvre selection. We suggest that performing an aerial as a first
306 manoeuvre is risky, and is rewarded, but that on average, surfers are more likely to
307 attempt an aerial as a first manoeuvre on waves that do not offer an overall high scoring
308 potential (e.g. a close-out or a generally poor wave). Put simply, we suggest it is not the

selection of the aerial early in the ride, but that aerials are being performed early in the ride on waves that do not have a very high scoring potential in the first place.

This effect can only be theorised if the aerial performed to finish the wave is deemed to be more influential than the rest of the manoeuvres performed on the wave previously. When assessing the key variables for a successful performance of an aerial; speed, height and acrobatic ability and landing (Lundgren et al., 2013; Ferrier et al., 2014), the section of the wave for the performance of this final manoeuvre would then need to be accommodating enough for the surfer to perform the aerial on. But anecdotally, for the surfer to produce the sufficient speed required for the take-off of an aerial manoeuvre, they would then miss prior opportunities for performing other manoeuvres, thus missing potential scoring opportunities and addressing the judging criteria of combination and variety of manoeuvres. This order of performance and where the aerial is placed in the sequence does seem to be an important aspect in the judging criteria and the performance. However, size of the section of the wave the aerial was performed on and number of previous manoeuvres prior to the aerial would be required to get a better understanding of the impact order and its impact on scoring potential.

In regards to time segment within the heat that the aerial manoeuvre was performed, the results were that the only significant difference in score awarded (P=0.041) was between the 2014 and 2015 seasons in the first third of the heat (Figure 4b). Plessner and Haar (2006) outlined that judges tend to use recall from previous scoring opportunities to base their scoring decision upon. Therefore, if judges utilise previous performances for scoring potential, a bias can then become evident, as there is potential for the judge to base the score from memory, and not the performance on its own merits. However, further research into judging and associated scoring is needed.

This finding has implications for the performing surfer and strategies within a heat. If the surfer strategically attempts to incorporate an aerial later in the heat, thinking it will influence the judges, the results show that this is a dangerous strategy to undertake. The findings instead indicate that a surfer should take the opportunity to perform an aerial when, and if, the wave allows the opportunity, with no real bias toward parts of a heat in relation to judging bias or creating a last ditch attempt to sway the judges. This along with where the aerial was performed in the wave sequence would further enhance performance and understanding of influence on score. If the surfer performed multiple manoeuvres and performed the aerial early in the sequence, landing spots like the bottom or the face of the wave would theoretically better enable the surfer to connect additional manoeuvres without losing too much speed or flow. But if they landed effectively in the other areas of the wave, this would mean the surfer would need to negotiate turbulence (white water) or the drop from the top of the wave to then connect to the next part of the wave. Therefore, the importance of the landing spot and the order of the aerial on the wave needs to be better understood to enable the surfer and coach a deeper understanding of the scoring potential.

PRACTICAL APPLICATION

This study highlights the importance of the inclusion of an aerial manoeuvre in a competitive surfing repetoire and further explains the impact of an aerial on scoring with regards to variation, completion rate, timing and the direction the surfer is facing when performing the aerial manoeuvre. We encourage surfers and coaches to endeavour to incorporate aerial manoeuvres, especially those that comply with the judging criteria. Therefore, those manoeuvres that require a high technical proficiency such as full rotations and alley oop’s on both the forehand and backhand have a tendency to be positively rewarded. Therefore, physical preparation and a skills based practice related to

the performance of this manoeuvre in surfing is important to maximise competitive performance. Especially when incorporating the more technically advanced variations such as the full rotation and alley oop variation.

With regards to timing of the manoeuvre, there is no reward seen over the three years with regards to strategy of inclusion of the manoeuvre. Therefore, we encourage the athlete to perform aerial manoeuvres when the wave dynamics allow the manoeuvre to be performed. As strategically incorporating an aerial manoeuvre late in the context of the heat may not be rewarded positively.

CONCLUSION

The results of the present study, in combination with earlier studies by Lundgren et al. (2013; 2014); Peirão and dos Santos (2012), Forsyth et al. (2017) and Ferrier et al. (2014) have all indicated that when a surfer incorporates an aerial into their performance, they will be rewarded with a higher score. When a surfer includes an aerial manoeuvre, our findings suggest the more technical variations such as an aerial reverse and full rotation are rewarded a higher score by the judges. With regards to heat strategy, results suggest there is no benefit to timing an aerial manoeuvre within the heat, or order of performance within a wave. But results do suggest that those aerials performed on the forehand are positively rewarded by the judging panel. Therefore, the authors suggest that a better understanding of the technical aspects to successfully perform an aerial manoeuvre are required to further assess the advent of this manoeuvre and its impact on the competitive aspect of surfing. It is clear however from the findings of this study and previous studies that a surfer's ability to perform an aerial continues to have a positive impact on competitive performance and the athlete's ability to score.

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Table One: Aerial Variation Classification and Definition

Aerial Variation	Definition
Straight	Where the board and rider are projected above the lip line of the wave with no rotation
Straight with Grab	As above, however the surfer grabs the rail of the board whilst in the air
Air Reverse	Where the rider and board rotate forward at least 180 degrees whilst in the air, before landing backwards
Air Reverse with Grab	As above, however the surfer grabs to rail of the board during the rotation
Full Rotation	Where the rider and board rotate forward at least 360 degrees whilst in the air, before landing
Full Rotation with Grab	As above, however the surfer grabs to rail of the board during the rotation
Alley Oop	Where the rider and board rotates backwards at least 180 degrees whilst in the air before landing back on the wave
Alley Oop with Grab	As above, however the surfer grabs to rail of the board during the rotation
Other	Any other variation of aerial variation that incorporates a variety of spins off axis or combination of grabs or rotations that do not fit into the above classifications.

Piter (2012)

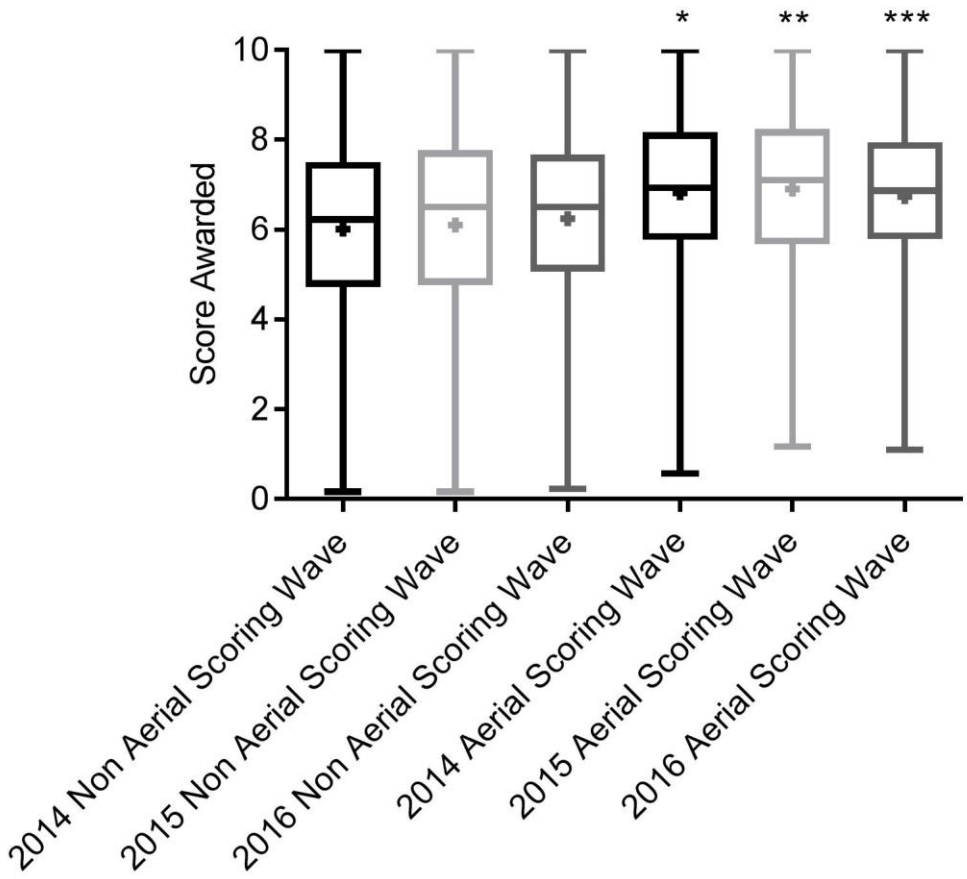
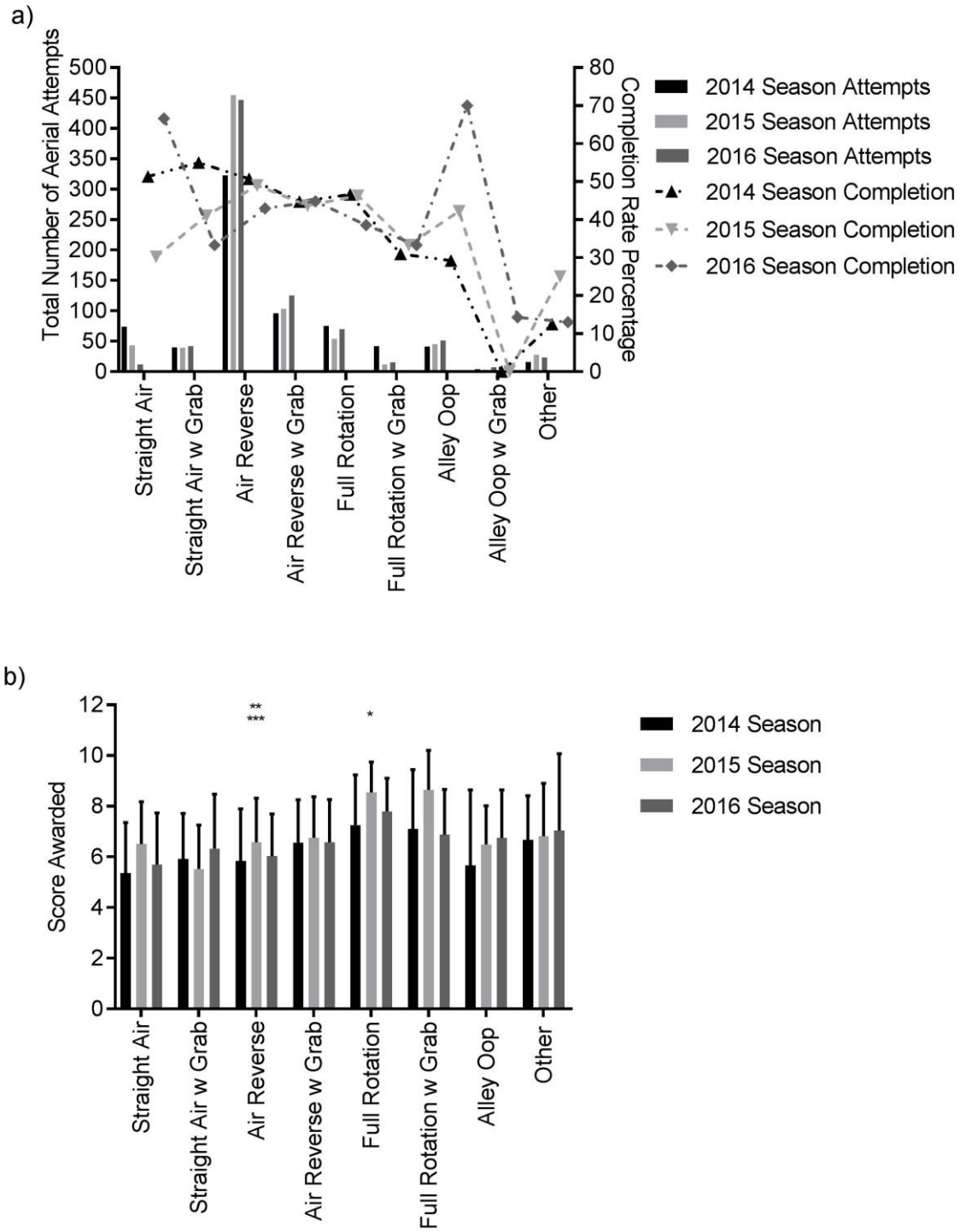


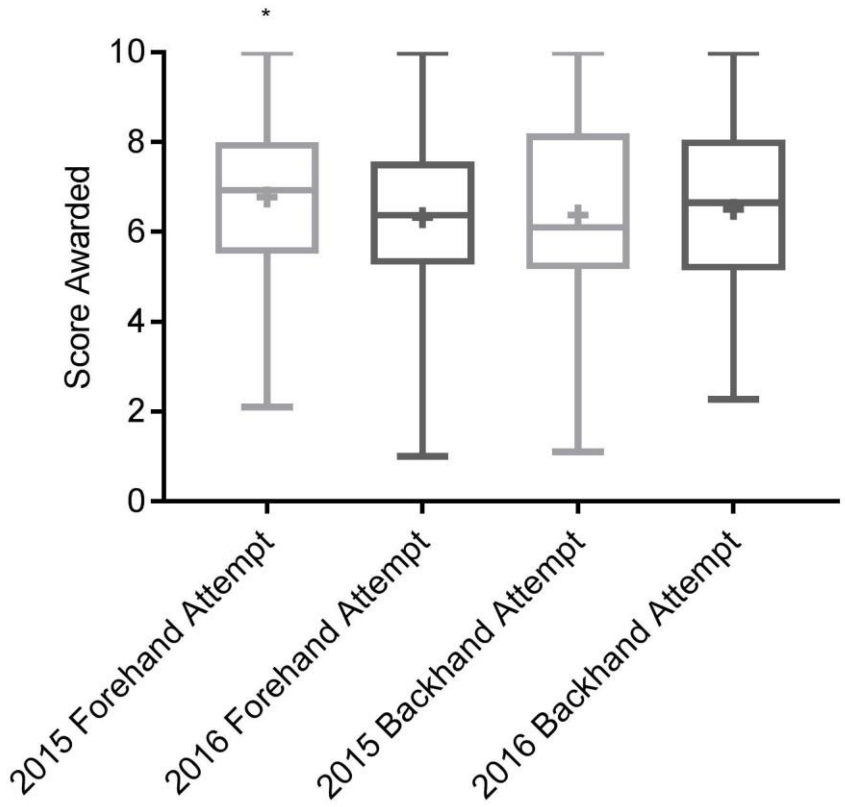
Figure One: Box and whisker plot of comparison of scores awarded to waves which counted as the top two wave scores that included an aerial compared to waves that did not include an aerial during the 2014, 2015 and 2016 WSL competitive season. Centre Line = median, top of box =75th percentile, bottom of box = 25th percentile, whiskers = data within the range of minimum and maximum score awarded, + = mean. * = significant difference ($p<0.0001$) between 2014 Non Aerial Scoring Wave and 2014 Aerial Scoring Wave. ** = significant difference ($p<0.0001$) between 2015 Non Aerial Scoring Wave and 2015 Aerial Scoring Wave. *** = significant difference ($p=0.0066$) between 2016 Non Aerial Scoring Wave and 2016 Aerial Scoring Wave.



443

444 **Figure Two:** Comparison of aerial variations performed during the 2014, 2015 and 2016 WSL seasons. (a)
445 Descriptive statistics of total number of aerial attempts and the overall completion rate of these attempts
446 and (b) Mean and standard deviation of the scores awarded for the successful completion of 8 aerial
447 variations. * = significant difference (p=0.0177) between the score awarded for the 2014 Full Rotation
448 Aerial and 2015 Full Rotation Aerial. ** = significant difference (p=0.0002) between the score awarded

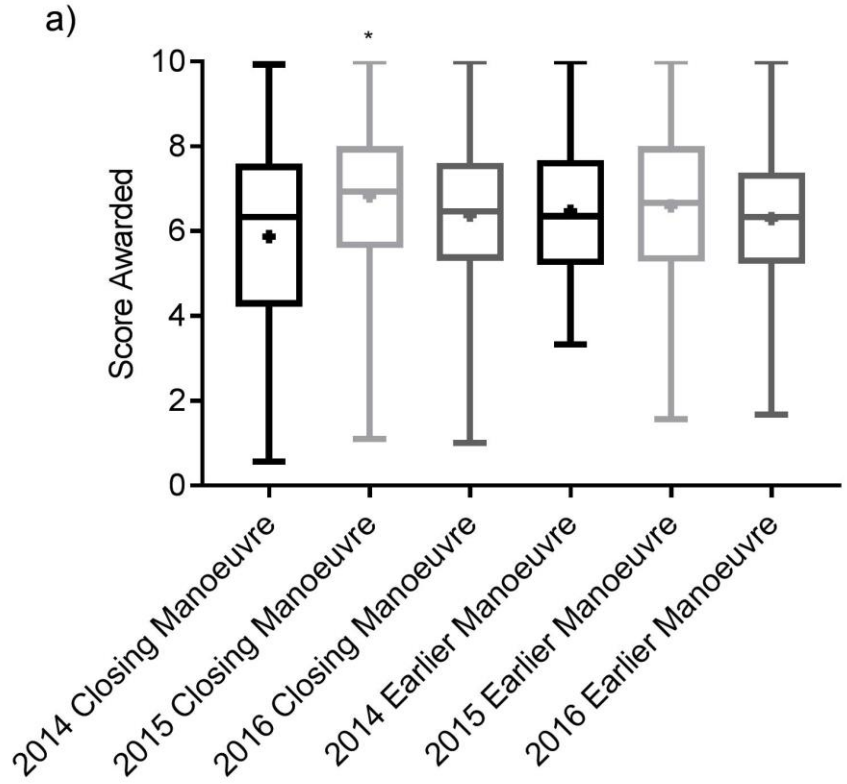
449 for the 2014 Air Reverse and 2015 Air Reverse. *** = significant difference (p=0.0057) between the score
450 awarded for the 2015 Air Reverse and 2016 Air Reverse.

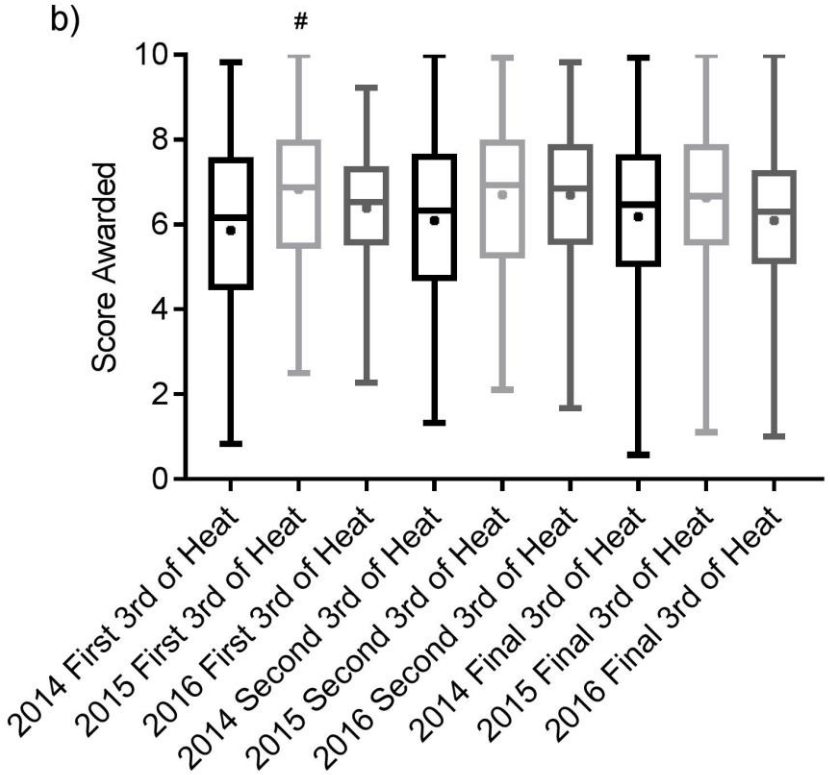


451

452 **Figure Three:** Box and whisker plot of temporal aspects related to the direction the surfer was facing on
453 the wave when the aerial manoeuvre was performed. Centre Line = median, top of box =75th percentile,
454 bottom of box = 25th percentile, whiskers = data within the range of minimum and maximum score awarded,
455 + = mean. * = significant difference in score awarded with 2016 forehand attempt (p=0.0113).

456


a)
*
Score Awarded
10
8
6
4
2
0
2014 Closing Manoeuvre
2015 Closing Manoeuvre
2016 Closing Manoeuvre
2014 Earlier Manoeuvre
2015 Earlier Manoeuvre
2016 Earlier Manoeuvre


b)
#
Score Awarded
10
8
6
4
2
0
2014 First 3rd of Heat
2015 First 3rd of Heat
2016 First 3rd of Heat
2014 Second 3rd of Heat
2015 Second 3rd of Heat
2016 Second 3rd of Heat
2014 Final 3rd of Heat
2015 Final 3rd of Heat
2016 Final 3rd of Heat

457

Figure Four: Box and whisker plot of temporal aspects related to when the aerial manoeuvre was performed. (a) Comparison of scores when the aerial manoeuvre was performed as the last move on the wave with performance of the aerial earlier in the sequence of manoeuvres. (b) Comparison of scores awarded for the wave when it was performed in the 1^{st}, 2^{nd} or 3^{rd} time interval of the heat. Centre Line = median, top of box =75^{th} percentile, bottom of box = 25^{th} percentile, whiskers = data within the range of minimum and maximum score awarded, + = mean. * = significant difference ($p<0.0001$) in score awarded for 2014 Closing Manoeuvre and 2015 Closing Manoeuvre. # = significant difference ($p=0.0027$) in score awarded for the inclusion of an aerial in the first third of the heat in 2014 and the score awarded for the inclusion of an aerial in the first third of the heat in 2015.

Scoring Analysis of the Men's 2014, 2015 and 2016 World Championship Tour of Surfing: The Importance of Aerial Manoeuvres in Competitive Surfing.

Research conducted at Hurley Surfing Australia High Performance Centre

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ABSTRACT

The aim of this study was to investigate the impact of aerial manoeuvres on scoring in professional surfing. 23631 waves were analysed for the number and types of aerial manoeuvres performed from the 2014, 2015 and 2016 Men's World Championship Tour. Additionally, the awarded score, timing and order of the aerial was also analysed. Descriptive statistics and Two Way ANOVA's were performed with Sidak Multiple Comparisons Post Hoc analysis. Results were a significantly higher score being awarded ($P \leq 0.0001$) when including an aerial in competition across all three seasons. In 2015 surfers were awarded a significantly larger score when performing an air reverse, compared to 2014 ($P=0.0002$) and 2016 ($P=0.0057$). Surfers were also awarded a higher score for the full rotation aerial in 2015 compared to 2014 ($P=0.0177$). In 2015 surfers performing forehand aerials were awarded a greater score than in 2016 ($P=0.0113$). The timing of the aerial and score awarded was significantly greater in 2015 as opposed to 2014 when the aerial was their final manoeuvre ($P<0.0001$) and when surfers timed the aerial performance early within the heat ($P=0.0027$). If a surfer incorporates an aerial manoeuvre during competition, generally speaking, they will be awarded a significantly higher score.

Keywords: Notational Analysis, Performance, Awarded Score, Coaching Impact

INTRODUCTION

In competitive surfing, the athlete's performance on each wave surfed is subjectively assessed on a scale of 0-10 points by a panel of 5 accredited judges. The judge's score is based on five key elements: 1) commitment and degree of difficulty; 2) innovative and progressive manoeuvres; 3) combination of major manoeuvres; 4) variety of manoeuvres; and 5) speed, power and flow (World Surf League [WSL], 2014). For a surfer's performance to be awarded a higher score, a combination of manoeuvres that address the 5 key elements in the most critical sections of the wave must be performed (Lundgren, Dunn, Nimphius, & Sheppard, 2013; Lundgren, Newton, Tran, Dunn, Nimphius, & Sheppard, 2014). The surfer with the highest two-wave total is deemed the winner of the heat. One of the most highly regarded manoeuvres in competitive surfing that has been linked with high performance and high risk is the aerial (Lundgren et al., 2014). The aerial manoeuvre incorporates the surfer launching themselves above the top of the wave then landing back on the same wave to continue their ride (Ferrier, Sheppard, Newton, & Nimphius, 2014).

The importance of the inclusion of an aerial manoeuvre was highlighted previously by Peirão and dos Santos (2012) during two Association of Surfing Professionals (ASP) competitions in 2007 and 2010. The study reported that the performance of an aerial manoeuvre when incorporated with a series of other manoeuvres had a low but significant correlation (r = 0.30; $P \leq 0.001$) with wave score. Additionally, our research team (Lundgren et al., 2014) also reported that surfers including an aerial manoeuvre during competitions were awarded an average score of 7.40 (±1.53) out of 10. In comparison, the same study highlighted that rides not including an aerial were on average, awarded a significantly lower (P<0.001) score of 5.08 (±2.21) during the 2012 ASP World Championship Tour. A recent study by Forsyth, de la Harpe, Riddiford-Harland,

Whitting, & Steele (2017) agreed with both previous studies reporting that during the 2015 World Championship Tour (WCT), surfers who included an aerial manoeuvre were awarded a significantly greater score than when they just performed manoeuvres on the wave face.

An interesting observation from the earlier study by Lundgren and associates (2014) was the aerial completion rate during competition. The authors highlighted that during competition, the completion rate of an aerial in competition was below 50% (Lundgren et al., 2014) outlining that it may be deemed a high risk manoeuvre to perform. Even with this low success rate, the three highlighted studies indicate that the inclusion of an aerial may still have a major influence on scoring potential. Tesler (2011) suggested that when a surfer includes an aerial manoeuvre whilst performing in competition, there is an inherent risk of either a wipe out or incomplete ride, thereby resulting in a lower score for that wave. However, with the recent changes to the scoring criteria, the risk and athleticism required to perform an aerial manoeuvre pairs itself well in the competitive situation, creating a risk-reward status for the surfer and their wave score when including an aerial manoeuvre. Recently, it has been observed within competition that the performance of an aerial alone (i.e. no other manoeuvres on that wave) can be deemed by the judges to address all the components of the judging criteria, and can be awarded the maximum 10 available points (Tesler, 2011).

Earlier, it was outlined by Farley, Raymond, Secomb, Ferrier, Lundgren, Tran, Abbiss, & Sheppard (2015) that the majority of studies in performance surfing have mainly focused on the physiological requirements (Farley, Harris, & Kilding, 2012), anthropometric variables (Barlow, Findlay, Gresty, & Cooke, 2014) and paddling performance (Sheppard, Osborne, Chapman, & Andrews, 2012) of elite level surfers. Such research has made major inroads into understanding the fitness requirements and physical attributes required for elite level competitive surfing. However, so far there is

limited published research regarding performance analysis in international competition and how the surfers choice of manoeuvre can influence scoring potential (Ferrier et al., 2014; Forsyth et al., 2017; Lundgren et al., 2013, 2014; Peirão and dos Santos, 2012).

Therefore, the aim of the current study was to investigate whether the inclusion of an aerial manoeuvre during competition continues to have a positive impact on scoring potential and whether this trend is evolving. The researchers sought to further investigate if the effect of aerial variation, order of manoeuvre during the surfing performance and timing of the aerial manoeuvre during the overall heat had an influence on competitive performance and scoring potential during the 2014, 2015 and 2016 Men's WCT. The findings of this study have potential to provide an insight into the effectiveness of including aerial manoeuvres in the wave riding repertoire, and whether the inclusion of an aerial manoeuvre and when it is performed during competition positively impacts the score awarded.

METHODS

All data were recorded for the 33 events carried out during the 2014 (n=11), 2015 (n=11) and 2016 (n=11) Men's WCT, where all waves (n=23631) surfed were analysed. Data collection was carried out between the months February 2014 through February 2017 from on-line video content available from the respective events heat analyser function available on the World Surf League website (WSL, 2014). The study and procedures were approved by Edith Cowan University Human Ethics Committee (approval number: 10320).

For each wave surfed, the number of manoeuvres were counted and further categorised as either including an aerial (n=2285) or non-aerial (n=21346). An aerial manoeuvre was classified as when the whole board and athlete's body was clear from the top of the wave, with the athlete's board and body in the air (Ferrier et al., 2014). This did not include a

free fall from a previous manoeuvre. The score awarded for all waves, as well as the awarded score for the waves counted as the surfer's top two scoring waves were noted from the World Surf League website (2014). The waves including a completed aerial attempt were then classified into 9 variations (Table One), with the order the aerial was performed on the wave also recorded. Each heat was divided into 3 equal time segments as heat times can range from 30 minutes to 40 minutes within a competition. This allowed for the calculation of temporal characteristics when each wave including an aerial manoeuvre was performed. Subsequently this allowed the authors to identify if the timing of the wave within the heat, including the aerial attempt, had an influence on scoring potential. In addition, for the 2015 and 2016 seasons, the surfers performance of the aerial was recorded and categorised to either forehand (surfer facing the wave when riding) or backhand (surfers back to the wave when riding) to investigate if the stance had an impact on the score awarded.

*******Table One Here*******

Statistical Analysis

Standard descriptive statistics of mean and standard deviations were calculated. A one-way repeated measures ANOVA was performed to determine significance of difference between aerial score, timing of aerial performance and direction the surfer was facing when the aerial was completed with the year of competition. A within variation two-way ANOVA was carried out to compare the differences in score awarded between years for each aerial variation performed. All data was assessed for normality using a D'Agostino test. In the event of the assumption of normality being violated the Greenhouse-Geisser correction adjustment was used. Where a significant difference was indicated a Sidak Multiple Comparisons Post Hoc Test was used to identify individual statistical variances. The magnitude of differences was evaluated by calculating effect sizes (Cohens *d*).

Magnitude of effect was based on the following criteria: >0.2, trivial; 0.2-0.5, small; 0.5-0.8, medium; and >0.8, large (Cohen, 1988). All statistical analyses were carried out using GraphPad Prism version 7.02 for Windows (GraphPad Software, LaJolla California USA, www.graphpad.com) with statistical significance being set at $P \leq 0.05$.

RESULTS

As outlined in Figure 1, there was a significant difference between the mean scores of the wave rides that incorporated an aerial manoeuvre (6.82, 6.91, 6.74), versus waves without an aerial (6.01, 6.10, 6.25) in the 2014, 2015 and 2016 seasons respectively R^2=0.012, $F(5,7690)$=16.86, P<=0.0001. Of the 2285 waves analysed that included an aerial, 711 aerials were attempted in 2014, 782 were attempted in 2015 and 792 were attempted in 2016. The most common variation of aerial attempted over the three years was the air reverse with 323 attempts in 2014, 455 attempts in 2015 and 447 attempts in 2016 (Figure 2a).

******FIGURE ONE HERE******

The completion rate of the air reverse aerial variation was 51% during the 2014 competitive season, 49% in 2015 and 43% in 2016. The aerial variation with the highest completion rate in 2014 was the straight air with a grab (55%), and in 2015 it was the air reverse (49%). During the 2016 season, the alley oop was the most successful variation with a completion rate of 70%. The variation with the least attempts across all years was the alley oop with grab (4 attempts in 2014, 3 attempts in 2015 and 7 attempts in 2016) with a 0% completion rate for both 2014 and 2015, and a single completion in 2016 (see Figure 2a).

******FIGURE TWO HERE******

The two way ANOVA indicated a significant and small effect difference R^2=0.5855, F(2,982)=3.028 in the score awarded between the 2014 (5.83 points ± 2.06 [5.52-6.15] 95% CI) vs 2015 (6.58 points ± 1.74 [6.35-6.81] 95% CI) (P=0.0002, d=0.39) and 2015 (6.58 points ± 1.74 [6.35-6.81] 95% CI) vs 2016 (6.02 points ± 1.67 [5.79-6.26] 95% CI), (P=0.006, d=0.32) seasons for the air reverse variation of aerials (Figure 2b). It is further indicated in figure 2b, when the surfer included a full rotation aerial during the 2015 season (8.55 points ± 1.20 [8.05-9.04] 95% CI), they received a significant and moderate increase in score (P=0.018, d=0.76) as opposed to performing the same aerial in 2014 (7.11 points ± 2.34 [5.69-8.52] 95% CI).

******FIGURE THREE HERE******

When the surfer performed an aerial on their forehand they were rewarded with a significant and small effect increase in score during 2015 (6.78 points ± 1.69 [6.59-6.98] 95% CI) than in 2016 (6.32 points ± 1.73 [6.12-6.52] 95% CI) R^2=0.015, F(3,675)=3.426. P=0.011, d=0.27. As indicated in figure 3, when comparing the scores for waves performed on the backhand the mean score for 2015 season (6.37 points ± 2.1 [5.83-6.92] 95% CI) was slightly lower, but not statistically different with a trivial effect than the score awarded in 2016 (6.51 points ± 2.06 [5.81-7.20] 95% CI) d=0.06.

It can be observed from figure 4a that there was a significant difference with a small effect R^2=0.028, F(5,1002)=5.856. P<0.0001 d=0.46 between scores awarded in 2014 (5.87 points ± 2.27 [5.58-6.17] 95% CI) for performing an aerial as the final manoeuvre, when compared with performing an aerial as a final manoeuvre in 2015 (6.83 points ± 1.74 [6.57-7.09] 95% CI). When we compared the scores for waves that ended with an aerial manoeuvre, the mean score for 2014 was almost one whole point lower than the score awarded in 2015. During the 2015 season, when an aerial was performed earlier in the

wave (6.59 points), they were also rewarded with a higher score than that in 2014 (6.47 points). The scores awarded in 2016 were identified to be lower than both 2014 and 2015.

******FIGURE FOUR HERE******

When we compared 2014 with the 2015 season a significant difference with a small to intermediate effect was indicated for the scores provided when aerials were performed in the first third of the heat (2014 season: 5.86 points ± 2.23 [5.40-6.32] 95% CI; 2015 season: 6.83 ± 1.79 [6.48-7.19] 95% CI) R^2=0.028, $F(8,999)=2.022$. P=0.0027 d=0.48. No other differences were observed in the score awarded within and between years, when compared to the timing of the heat. Scores awarded by the judges across the three time variables (Figure 4b) in 2015 were slightly higher.

DISCUSSION

This study aimed to investigate the influence on score awarded when including an aerial manoeuvre during competition. The inclusion of an aerial had a significant influence on the score awarded for the top two scoring waves across all three seasons (P<0.05), when compared to those waves which did not include an aerial manoeuvre (Figure 1). This difference of 0.80, 0.81 and 0.49 of a score in 2014, 2015 and 2016 respectively, was considered to have a small effect. Nevertheless, the difference between winning and losing a heat can be determined by a score as small as 0.01. The small, but significant differences can have a large impact on the surfers' ability to progress through a competition and improve their ranking as outlined by Farley and colleagues (2015). Farley et al (2015) found that the top 10 ranked surfers over the 2013 WCT season scored on average 1.04 more points per wave when compared to lower ranked surfers. Therefore, the inclusion of an aerial and the potential impact it has on scoring appears very important for bridging the gap between lower ranked surfers and the top 10 in elite level surfing athletes. Farley and associates (2015) further outlined that consistency and lower

variability within heat and individual wave score had a positive influence on competitive performance. Meaning that not only the inclusion of an aerial, but the successful performance of the manoeuvre may influence scoring potential.

When the surfer incorporated an aerial into competitive performance, the results of the current study are similar to earlier studies on scoring in competitive surfing by Lundgren and associates (2013; 2014). For the present study however, only the top two scoring waves for each surfer in each heat were analysed with regards to the overall impact of including an aerial manoeuvre during performance. This provided insights as to whether inclusion of an aerial into the performance positively influenced scoring potential, and the surfer's overall competitive performance. It is evident that during competition, both the inclusion and exclusion of an aerial manoeuvre are awarded a large range of scores (Figure 1). However, as previously outlined, the change in scoring criteria and the high risk associated with an aerial manoeuvre (Tesler, 2011) has enabled the judges to reward the surfer who incorporated an aerial in their wave riding repertoire. Therefore, the scoring potential when including an aerial manoeuvre during competitive performance has a positive impact on scoring potential (Lundgren et al., 2013, 2014; Souza et al., 2012; Piter, 2012).

Due to a vast amount of variables associated with surfing (wave formation, type of break, intensity, quality, environment etc.), waves are never the same and therefore, each wave has great influence in the variation and ability to perform manoeuvres and aerial manoeuvres (Lundgren et al, 2014; Peirão, & dos Santos, 2012). For the surfer to create the optimal velocity to leave the wave and perform an aerial manoeuvre, they need to perform the aerial within the steep part of the wave face, close to the pitching lip of the wave (Piter, 2012). This part of the wave is deemed the critical section of the wave, with judges looking for manoeuvres being as close to the pitching part of the wave to satisfy the judging criteria. However, with this steepness in the wave and the speed of the

breaking wave, performing manoeuvres in this part of the wave has been determined to be high risk for completion (Surfing Australia, 2014; International Surfing Association, 2015; World Surf League, 2017). Therefore, for the surfer to perform a highly complex manoeuvre, such as an aerial in a critical part of the wave, the successful completion of a high risk aerial manoeuvre fulfils the judges scoring criteria and results in the surfer being rewarded with a higher score.

From the results (Figure 2a) it can be identified that the ability of the surfer to complete an aerial manoeuvre during both the 2014 and 2015 seasons is below 55%. This completion rate is somewhat lower compared to the completion rates of turning manoeuvres, which were found to be above 90% (Lundgren et al., 2014; Souza et al., 2012). This result may indicate that when the surfer performs and completes an aerial manoeuvre, the surfer is rewarded by the judges with a higher score (Figure 1), whilst potentially increasing the chances of that wave counting as one of the surfer's top two scoring waves. An interesting observation made during analysing the 2016 season was that both the straight air (67%) and alley oop (70%) improved markedly in completion rate from the previous two seasons (Figure 2a). Further analysis revealed that 50% of the straight air attempts (6 aerials) were counted within the surfers' top two scoring waves (12 attempts). This information indicates that when the surfer performed this manoeuvre successfully the aerial was possibly rewarded by the judges. This can be further supported by the single Alley Oop with a grab that was successfully performed in 2016. This aerial variation was positively rewarded by the judges with a score of 7.83, which was 1.08 points higher than the score provided for those performing the same aerial variation without a grab (n=21 mean=6.75 points) in the same year. However, future studies focussed on judging and award of score would need to be carried out to verify this.

With reference to the difference in variations of aerial types and score awarded there was found to be a significant difference in the scores awarded between seasons for both the

air reverse and full rotation (Figure 2b). Analysis reveals the air reverse variation is the most common form of aerial attempted in competition (Figure 2a) with 2015 being the year that judges rewarded the surfer with higher scores than in both 2014 (0.74 of a point) and 2016 (0.55 of a point). Of the eight other variations, the full rotation which requires a full 360^0 rotation as opposed to the 180^0 rotation seen in the air reverse was the only other variation that provided significant results. When comparing the 2014 and 2015 seasons for the full rotation (Figure 2b), the score provided in 2015 was 1.3 points higher than 2014 (P=0.0177).

Forsyth et al. (2017) suggested that during the final series of the 2015 season, the forehand straight and forehand full rotation were awarded higher scores than the forehand air reverse. However, with the current study and that carried out by Forsyth and associates (2017), aspects such as other manoeuvres performed on the wave, orientation and axis of rotation of the aerial (technical aspects) have not been quantified. These components all impact on the overall wave performance and aesthetics of the aerial manoeuvre. But when considering the 5 key elements of scoring and the inclusion of aerial manoeuvres, judges need to consider the additional 180^0 rotation within the context of the criteria. By increasing the technical ability of the surfer, this may enable the surfer to add a further dimension to the variation performed increasing their scoring potential. This additional complexity above the lip of the wave also addresses the key judging components of difficulty, commitment, innovation and progression.

The direction the surfer faced during the wave ride also indicated a seasonal effect with regards to scoring potential. During the 2015 season, the score awarded for aerials performed on the forehand (facing the wave face) were awarded a significantly (P=0.0113) greater score than those in 2016 (Figure 3). No difference was seen in the score awarded when the surfer performed an aerial on their backhand for either the 2015 and 2016 seasons or when compared to performing an aerial on the forehand. However,

further analysis by Forsyth and associates (2017) during the final series identified for the air reverse manoeuvre in 2015, the backhand attempts were awarded a higher score than forehand attempts. Although this and previous results related to forehand aerials by Forsyth and colleagues (2017) do show a trend in scoring potential, these scores awarded were not significantly different and did not look at the performance leading up to the finals. Furthermore, we cannot make broad based conslusions about the meaningfulness of forehand and backhand aerials and scoring potential, due to methodological reasons that we were not able to overcome. In surfing, a backhand aerial is more difficult for the vast majority of participants, suggesting that this should feature higher in the judging criteria. However, this may also suggest that the forehand airs are better (bigger flight height and time, greater control and grab execution, more dynamic rotation), because the surfers are able to gain better speed and be more precise in their execution.

When the surfer performed the aerial manoeuvre as the final move on the wave, it was awarded a greater score ($P<0.0001$) in the 2015 season (Figure 4a) than when surfers successfully performed an aerial as a final move in 2014 (0.955 of a point difference). However, within seasons there does not seem to be an effect with regards to order of performance of an aerial manoeuvre. Within a coaching aspect choosing to perform a higher risk manoeuvre like an aerial, earlier in the sequence of manoeuvres, does increase the risk of not completing the wave, which would result in a score so low it would likely not factor into the top two scores in order to win a heat. As such, this risk is associated with a higher reward. However, our finding must be interpreted in the broader context of wave selection and manoeuvre selection. We suggest that performing an aerial as a first manoeuvre is risky, and is rewarded, but that on average, surfers are more likely to attempt an aerial as a first manoeuvre on waves that do not offer an overall high scoring potential (e.g. a close-out or a generally poor wave). Put simply, we suggest it is not the

selection of the aerial early in the ride, but that aerials are being performed early in the ride on waves that do not have a very high scoring potential in the first place.

This effect can only be theorised if the aerial performed to finish the wave is deemed to be more influential than the rest of the manoeuvres performed on the wave previously. When assessing the key variables for a successful performance of an aerial; speed, height and acrobatic ability and landing (Lundgren et al., 2013; Ferrier et al., 2014), the section of the wave for the performance of this final manoeuvre would then need to be accommodating enough for the surfer to perform the aerial on. But anecdotally, for the surfer to produce the sufficient speed required for the take-off of an aerial manoeuvre, they would then miss prior opportunities for performing other manoeuvres, thus missing potential scoring opportunities and addressing the judging criteria of combination and variety of manoeuvres. This order of performance and where the aerial is placed in the sequence does seem to be an important aspect in the judging criteria and the performance. However, size of the section of the wave the aerial was performed on and number of previous manoeuvres prior to the aerial would be required to get a better understanding of the impact order and its impact on scoring potential.

In regards to time segment within the heat that the aerial manoeuvre was performed, the results were that the only significant difference in score awarded (P=0.041) was between the 2014 and 2015 seasons in the first third of the heat (Figure 4b). Plessner and Haar (2006) outlined that judges tend to use recall from previous scoring opportunities to base their scoring decision upon. Therefore, if judges utilise previous performances for scoring potential, a bias can then become evident, as there is potential for the judge to base the score from memory, and not the performance on its own merits. However, further research into judging and associated scoring is needed.

This finding has implications for the performing surfer and strategies within a heat. If the surfer strategically attempts to incorporate an aerial later in the heat, thinking it will influence the judges, the results show that this is a dangerous strategy to undertake. The findings instead indicate that a surfer should take the opportunity to perform an aerial when, and if, the wave allows the opportunity, with no real bias toward parts of a heat in relation to judging bias or creating a last ditch attempt to sway the judges. This along with where the aerial was performed in the wave sequence would further enhance performance and understanding of influence on score. If the surfer performed multiple manoeuvres and performed the aerial early in the sequence, landing spots like the bottom or the face of the wave would theoretically better enable the surfer to connect additional manoeuvres without losing too much speed or flow. But if they landed effectively in the other areas of the wave, this would mean the surfer would need to negotiate turbulence (white water) or the drop from the top of the wave to then connect to the next part of the wave. Therefore, the importance of the landing spot and the order of the aerial on the wave needs to be better understood to enable the surfer and coach a deeper understanding of the scoring potential.

PRACTICAL APPLICATION

This study highlights the importance of the inclusion of an aerial manoeuvre in a competitive surfing repetoire and further explains the impact of an aerial on scoring with regards to variation, completion rate, timing and the direction the surfer is facing when performing the aerial manoeuvre. We encourage surfers and coaches to endeavour to incorporate aerial manoeuvres, especially those that comply with the judging criteria. Therefore, those manoeuvres that require a high technical proficiency such as full rotations and alley oop's on both the forehand and backhand have a tendency to be positively rewarded. Therefore, physical preparation and a skills based practice related to

the performance of this manoeuvre in surfing is important to maximise competitive performance. Especially when incorporating the more technically advanced variations such as the full rotation and alley oop variation.

With regards to timing of the manoeuvre, there is no reward seen over the three years with regards to strategy of inclusion of the manoeuvre. Therefore, we encourage the athlete to perform aerial manoeuvres when the wave dynamics allow the manoeuvre to be performed. As strategically incorporating an aerial manoeuvre late in the context of the heat may not be rewarded positively.

CONCLUSION

The results of the present study, in combination with earlier studies by Lundgren et al. (2013; 2014); Peirão and dos Santos (2012), Forsyth et al. (2017) and Ferrier et al. (2014) have all indicated that when a surfer incorporates an aerial into their performance, they will be rewarded with a higher score. When a surfer includes an aerial manoeuvre, our findings suggest the more technical variations such as an aerial reverse and full rotation are rewarded a higher score by the judges. With regards to heat strategy, results suggest there is no benefit to timing an aerial manoeuvre within the heat, or order of performance within a wave. But results do suggest that those aerials performed on the forehand are positively rewarded by the judging panel. Therefore, the authors suggest that a better understanding of the technical aspects to successfully perform an aerial manoeuvre are required to further assess the advent of this manoeuvre and its impact on the competitive aspect of surfing. It is clear however from the findings of this study and previous studies that a surfer's ability to perform an aerial continues to have a positive impact on competitive performance and the athlete's ability to score.

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Table One: Aerial Variation Classification and Definition

Aerial Variation	Definition
Straight	Where the board and rider are projected above the lip line of the wave with no rotation
Straight with Grab	As above, however the surfer grabs the rail of the board whilst in the air
Air Reverse	Where the rider and board rotate forward at least 180 degrees whilst in the air, before landing backwards
Air Reverse with Grab	As above, however the surfer grabs to rail of the board during the rotation
Full Rotation	Where the rider and board rotate forward at least 360 degrees whilst in the air, before landing
Full Rotation with Grab	As above, however the surfer grabs to rail of the board during the rotation
Alley Oop	Where the rider and board rotates backwards at least 180 degrees whilst in the air before landing back on the wave
Alley Oop with Grab	As above, however the surfer grabs to rail of the board during the rotation
Other	Any other variation of aerial variation that incorporates a variety of spins off axis or combination of grabs or rotations that do not fit into the above classifications.

Piter (2012)

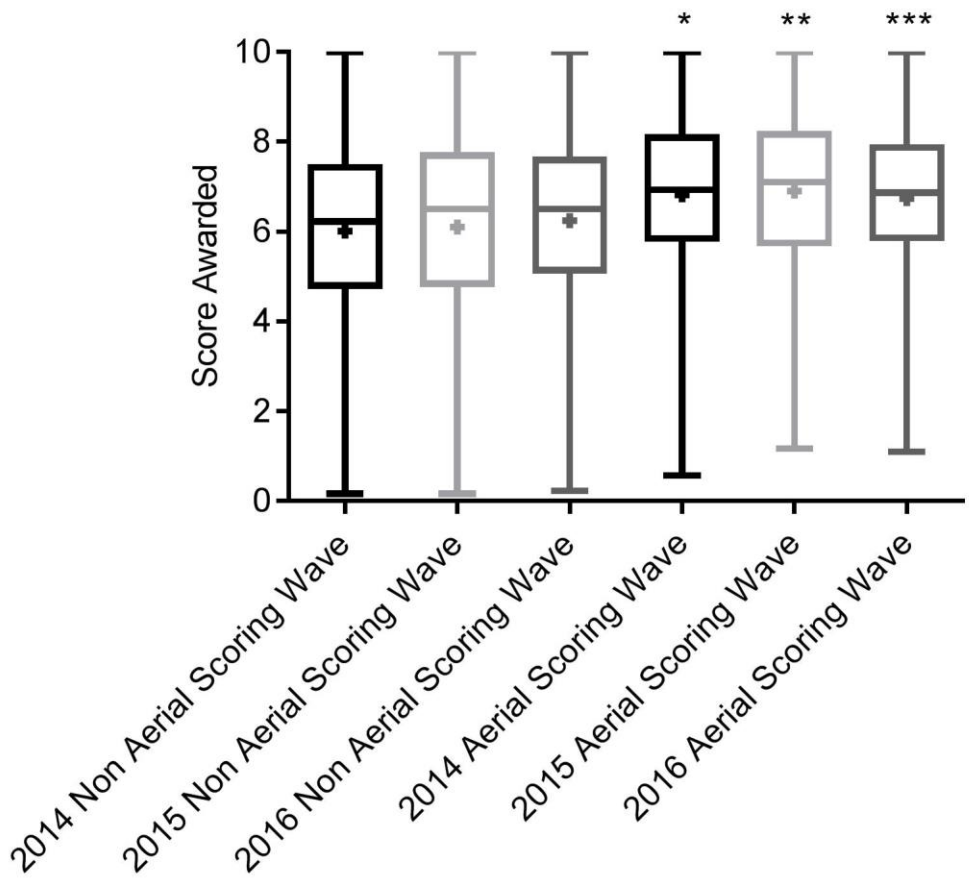


Figure One: Box and whisker plot of comparison of scores awarded to waves which counted as the top two wave scores that included an aerial compared to waves that did not include an aerial during the 2014, 2015 and 2016 WSL competitive season. Centre Line = median, top of box =75th percentile, bottom of box = 25th percentile, whiskers = data within the range of minimum and maximum score awarded, + = mean. * = significant difference ($p<0.0001$) between 2014 Non Aerial Scoring Wave and 2014 Aerial Scoring Wave. ** = significant difference ($p<0.0001$) between 2015 Non Aerial Scoring Wave and 2015 Aerial Scoring Wave. *** = significant difference ($p=0.0066$) between 2016 Non Aerial Scoring Wave and 2016 Aerial Scoring Wave.

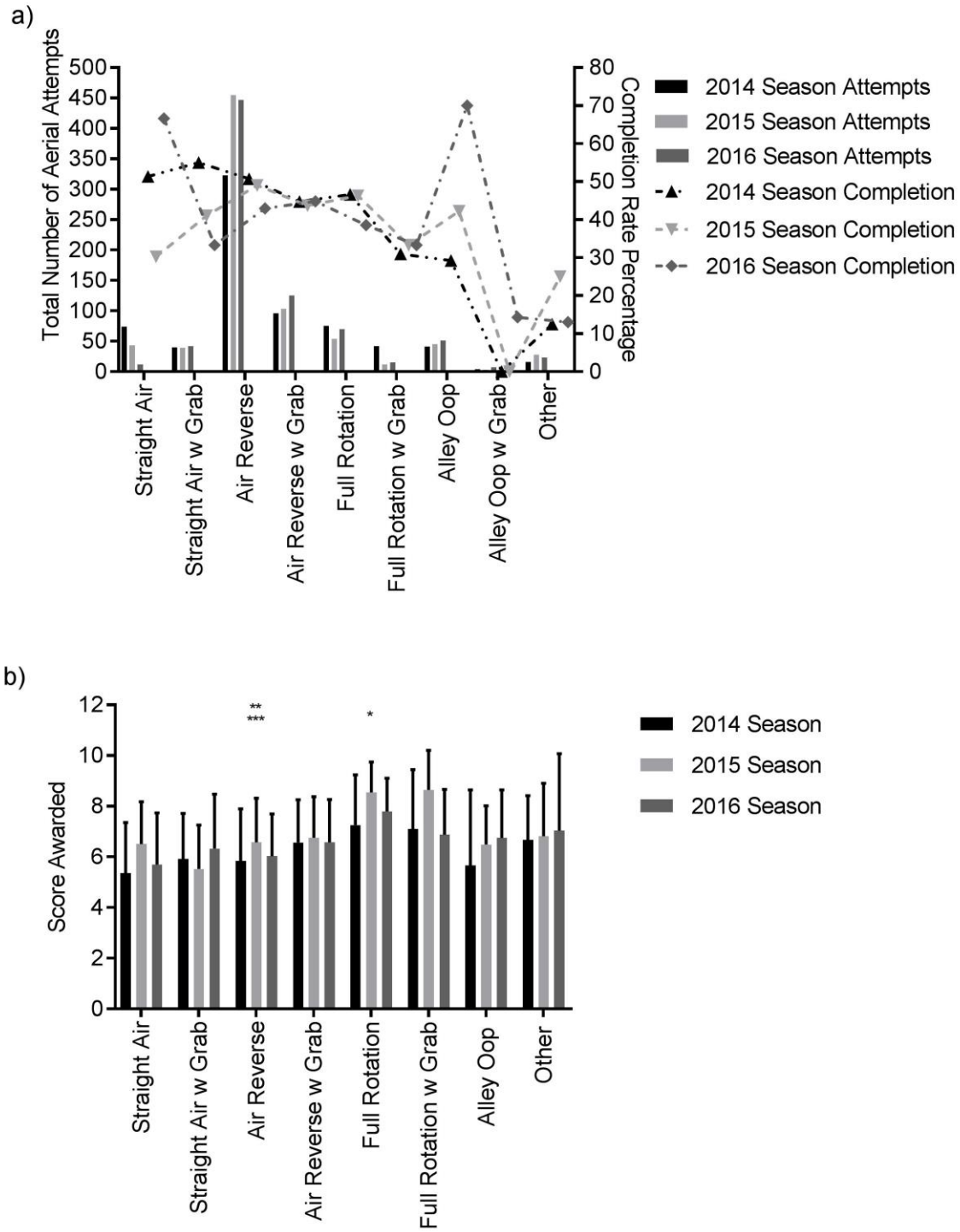


Figure Two: Comparison of aerial variations performed during the 2014, 2015 and 2016 WSL seasons. (a) Descriptive statistics of total number of aerial attempts and the overall completion rate of these attempts and (b) Mean and standard deviation of the scores awarded for the successful completion of 8 aerial variations. * = significant difference (p=0.0177) between the score awarded for the 2014 Full Rotation Aerial and 2015 Full Rotation Aerial. ** = significant difference (p=0.0002) between the score awarded

for the 2014 Air Reverse and 2015 Air Reverse. *** = significant difference (p=0.0057) between the score awarded for the 2015 Air Reverse and 2016 Air Reverse.

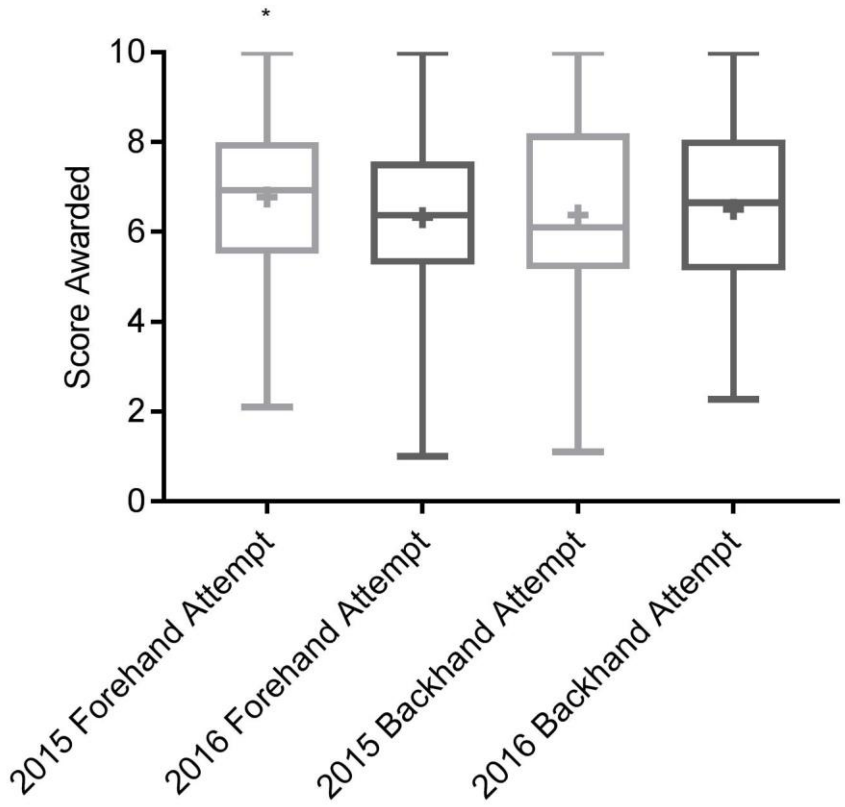
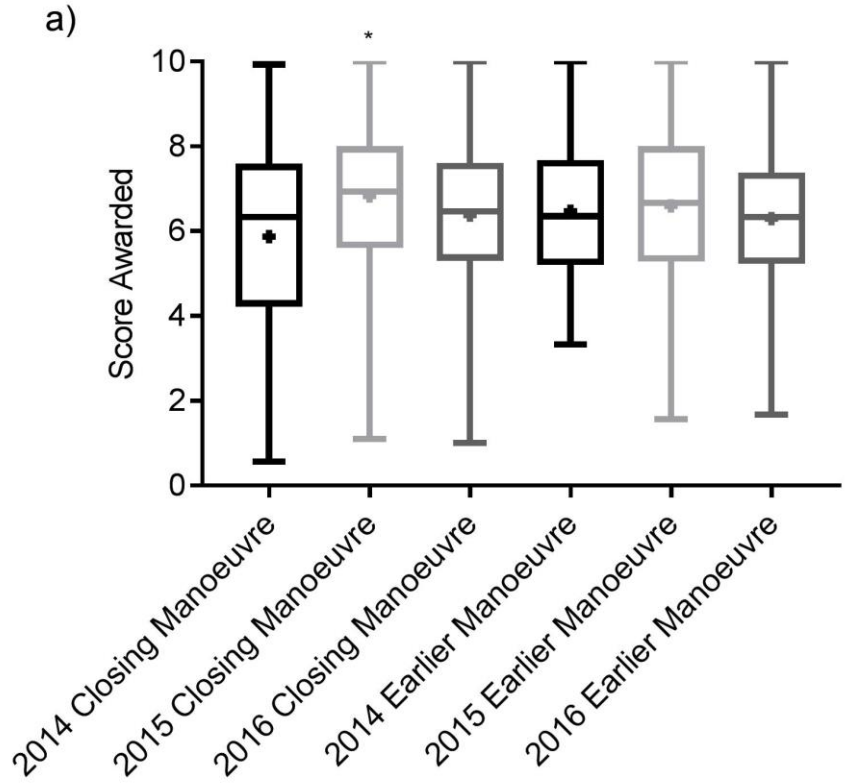
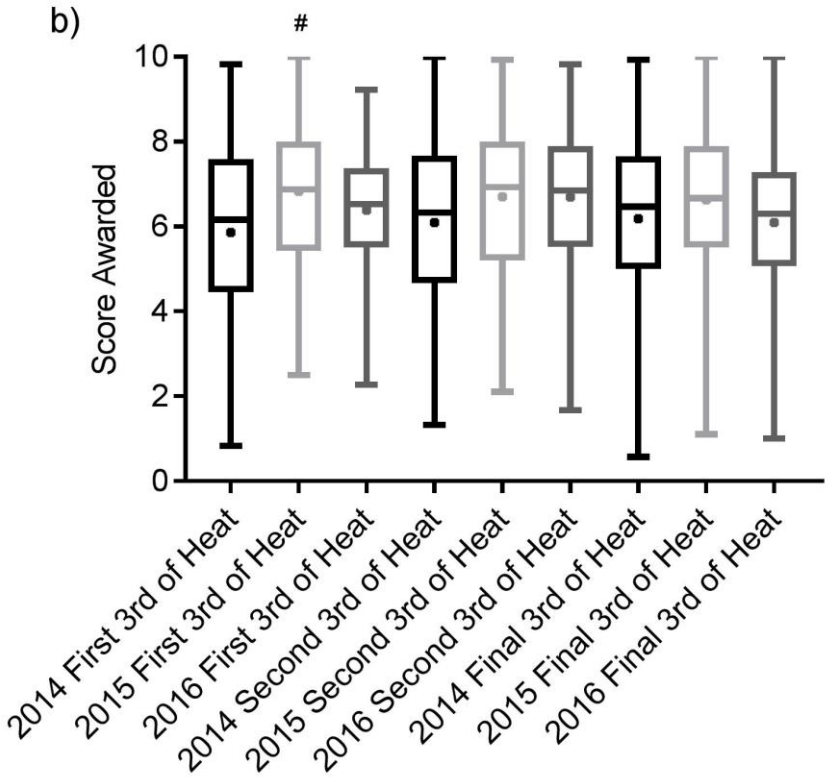


Figure Three: Box and whisker plot of temporal aspects related to the direction the surfer was facing on the wave when the aerial manoeuvre was performed. Centre Line = median, top of box =75th percentile, bottom of box = 25th percentile, whiskers = data within the range of minimum and maximum score awarded, + = mean. * = significant difference in score awarded with 2016 forehand attempt (p=0.0113).


a)
*
Score Awarded
10
8
6
4
2
0
2014 Closing Manoeuvre
2015 Closing Manoeuvre
2016 Closing Manoeuvre
2014 Earlier Manoeuvre
2015 Earlier Manoeuvre
2016 Earlier Manoeuvre


b)
#
Score Awarded
10
8
6
4
2
0
2014 First 3rd of Heat
2015 First 3rd of Heat
2016 First 3rd of Heat
2014 Second 3rd of Heat
2015 Second 3rd of Heat
2016 Second 3rd of Heat
2014 Final 3rd of Heat
2015 Final 3rd of Heat
2016 Final 3rd of Heat

475

Figure Four: Box and whisker plot of temporal aspects related to when the aerial manoeuvre was performed. (a) Comparison of scores when the aerial manoeuvre was performed as the last move on the wave with performance of the aerial earlier in the sequence of manoeuvres. (b) Comparison of scores awarded for the wave when it was performed in the 1^{st}, 2^{nd} or 3^{rd} time interval of the heat. Centre Line = median, top of box =75^{th} percentile, bottom of box = 25^{th} percentile, whiskers = data within the range of minimum and maximum score awarded, + = mean. * = significant difference ($p<0.0001$) in score awarded for 2014 Closing Manoeuvre and 2015 Closing Manoeuvre. # = significant difference ($p=0.0027$) in score awarded for the inclusion of an aerial in the first third of the heat in 2014 and the score awarded for the inclusion of an aerial in the first third of the heat in 2015.