

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

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3 The aim of this study was to investigate the impact of aerial manoeuvres on scoring in
4 professional surfing. 23631 waves were analysed for the number and types of aerial
5 manoeuvres performed from the 2014, 2015 and 2016 Men's World Championship Tour.
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7 Additionally, the awarded score, timing and order of the aerial was also analysed.
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9 Descriptive statistics and Two Way ANOVA's were performed with Sidak Multiple
10 Comparisons Post Hoc analysis. Results were a significantly higher score being awarded
11 ($P \leq 0.0001$) when including an aerial in competition across all three seasons. In 2015
12 surfers were awarded a significantly larger score when performing an air reverse,
13 compared to 2014 ($P=0.0002$) and 2016 ($P=0.0057$). Surfers were also awarded a higher
14 score for the full rotation aerial in 2015 compared to 2014 ($P=0.0177$). In 2015 surfers
15 performing forehand aerials were awarded a greater score than in 2016 ($P=0.0113$). The
16 timing of the aerial and score awarded was significantly greater in 2015 as opposed to
17 2014 when the aerial was their final manoeuvre ($P < 0.0001$) and when surfers timed the
18 aerial performance early within the heat ($P=0.0027$). If a surfer incorporates an aerial
19 manoeuvre during competition, generally speaking, they will be awarded a significantly
20 higher score.
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45 **Keywords:** Notational Analysis, Performance, Awarded Score, Coaching Impact
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INTRODUCTION

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3 In competitive surfing, the athlete's performance on each wave surfed is subjectively
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5 assessed on a scale of 0-10 points by a panel of 5 accredited judges. The judge's score is
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7 based on five key elements: 1) commitment and degree of difficulty; 2) innovative and
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9 progressive manoeuvres; 3) combination of major manoeuvres; 4) variety of manoeuvres;
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11 and 5) speed, power and flow (World Surf League [WSL], 2014). For a surfer's
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13 performance to be awarded a higher score, a combination of manoeuvres that address the
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15 5 key elements in the most critical sections of the wave must be performed (Lundgren,
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17 Dunn, Nimphius, & Sheppard, 2013; Lundgren, Newton, Tran, Dunn, Nimphius, &
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19 Sheppard, 2014). The surfer with the highest two-wave total is deemed the winner of the
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21 heat. One of the most highly regarded manoeuvres in competitive surfing that has been
22
23 linked with high performance and high risk is the aerial (Lundgren et al., 2014). The aerial
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25 manoeuvre incorporates the surfer launching themselves above the top of the wave then
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27 landing back on the same wave to continue their ride (Ferrier, Sheppard, Newton, &
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29 Nimphius, 2014).

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32 The importance of the inclusion of an aerial manoeuvre was highlighted previously by
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34 Peirão and dos Santos (2012) during two Association of Surfing Professionals (ASP)
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36 competitions in 2007 and 2010. The study reported that the performance of an aerial
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38 manoeuvre when incorporated with a series of other manoeuvres had a low but significant
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40 correlation ($r = 0.30$; $P \leq 0.001$) with wave score. Additionally, our research team
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42 (Lundgren et al., 2014) also reported that surfers including an aerial manoeuvre during
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44 competitions were awarded an average score of 7.40 (± 1.53) out of 10. In comparison,
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46 the same study highlighted that rides not including an aerial were on average, awarded a
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48 significantly lower ($P < 0.001$) score of 5.08 (± 2.21) during the 2012 ASP World
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50 Championship Tour. A recent study by Forsyth, de la Harpe, Riddiford-Harland,
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1 Whitting, & Steele (2017) agreed with both previous studies reporting that during the
2 2015 World Championship Tour (WCT), surfers who included an aerial manoeuvre were
3 awarded a significantly greater score than when they just performed manoeuvres on the
4 wave face.
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9 An interesting observation from the earlier study by Lundgren and associates (2014) was
10 the aerial completion rate during competition. The authors highlighted that during
11 competition, the completion rate of an aerial in competition was below 50% (Lundgren
12 et al., 2014) outlining that it may be deemed a high risk manoeuvre to perform. Even with
13 this low success rate, the three highlighted studies indicate that the inclusion of an aerial
14 may still have a major influence on scoring potential. Tesler (2011) suggested that when
15 a surfer includes an aerial manoeuvre whilst performing in competition, there is an
16 inherent risk of either a wipe out or incomplete ride, thereby resulting in a lower score for
17 that wave. However, with the recent changes to the scoring criteria, the risk and
18 athleticism required to perform an aerial manoeuvre pairs itself well in the competitive
19 situation, creating a risk-reward status for the surfer and their wave score when including
20 an aerial manoeuvre. Recently, it has been observed within competition that the
21 performance of an aerial alone (i.e. no other manoeuvres on that wave) can be deemed by
22 the judges to address all the components of the judging criteria, and can be awarded the
23 maximum 10 available points (Tesler, 2011).
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46 Earlier, it was outlined by Farley, Raymond, Secomb, Ferrier, Lundgren, Tran, Abbiss,
47 & Sheppard (2015) that the majority of studies in performance surfing have mainly
48 focused on the physiological requirements (Farley, Harris, & Kilding, 2012),
49 anthropometric variables (Barlow, Findlay, Gresty, & Cooke, 2014) and paddling
50 performance (Sheppard, Osborne, Chapman, & Andrews, 2012) of elite level surfers.
51 Such research has made major inroads into understanding the fitness requirements and
52 physical attributes required for elite level competitive surfing. However, so far there is
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1 limited published research regarding performance analysis in international competition
2 and how the surfers choice of manoeuvre can influence scoring potential (Ferrier et al.,
3 2014; Forsyth et al., 2017; Lundgren et al., 2013, 2014; Peirão and dos Santos, 2012).
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6 Therefore, the aim of the current study was to investigate whether the inclusion of an
7 aerial manoeuvre during competition continues to have a positive impact on scoring
8 potential and whether this trend is evolving. The researchers sought to further investigate
9 if the effect of aerial variation, order of manoeuvre during the surfing performance and
10 timing of the aerial manoeuvre during the overall heat had an influence on competitive
11 performance and scoring potential during the 2014, 2015 and 2016 Men's WCT. The
12 findings of this study have potential to provide an insight into the effectiveness of
13 including aerial manoeuvres in the wave riding repertoire, and whether the inclusion of
14 an aerial manoeuvre and when it is performed during competition positively impacts the
15 score awarded.
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31 METHODS 32

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35 All data were recorded for the 33 events carried out during the 2014 (n=11), 2015 (n=11)
36 and 2016 (n=11) Men's WCT, where all waves (n=23631) surfed were analysed. Data
37 collection was carried out between the months February 2014 through February 2017
38 from on-line video content available from the respective events heat analyser function
39 available on the World Surf League website (WSL, 2014). The study and procedures were
40 approved by Edith Cowan University Human Ethics Committee (approval number:
41 10320).
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52 For each wave surfed, the number of manoeuvres were counted and further categorised
53 as either including an aerial (n=2285) or non-aerial (n=21346). An aerial manoeuvre was
54 classified as when the whole board and athlete's body was clear from the top of the wave,
55 with the athlete's board and body in the air (Ferrier et al., 2014). This did not include a
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1 free fall from a previous manoeuvre. The score awarded for all waves, as well as the
2 awarded score for the waves counted as the surfer's top two scoring waves were noted
3 from the World Surf League website (2014). The waves including a completed aerial
4 attempt were then classified into 9 variations (Table One), with the order the aerial was
5 performed on the wave also recorded. Each heat was divided into 3 equal time segments
6 as heat times can range from 30 minutes to 40 minutes within a competition. This allowed
7 for the calculation of temporal characteristics when each wave including an aerial
8 manoeuvre was performed. Subsequently this allowed the authors to identify if the timing
9 of the wave within the heat, including the aerial attempt, had an influence on scoring
10 potential. In addition, for the 2015 and 2016 seasons, the surfers performance of the aerial
11 was recorded and categorised to either forehand (surfer facing the wave when riding) or
12 backhand (surfers back to the wave when riding) to investigate if the stance had an impact
13 on the score awarded.

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

32 33 34 35 36 **Statistical Analysis**

37 Standard descriptive statistics of mean and standard deviations were calculated. A one-
38 way repeated measures ANOVA was performed to determine significance of difference
39 between aerial score, timing of aerial performance and direction the surfer was facing
40 when the aerial was completed with the year of competition. A within variation two-way
41 ANOVA was carried out to compare the differences in score awarded between years for
42 each aerial variation performed. All data was assessed for normality using a D'Agostino
43 test. In the event of the assumption of normality being violated the Greenhouse-Geisser
44 correction adjustment was used. Where a significant difference was indicated a Sidak
45 Multiple Comparisons Post Hoc Test was used to identify individual statistical variances.
46 The magnitude of differences was evaluated by calculating effect sizes (Cohens *d*).
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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 $R^2=0.012$, $F(5,7690)=16.86$, $P \leq 0.0001$. 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****

1 The two way ANOVA indicated a significant and small effect difference $R^2=0.5855$,
2 $F(2,982)=3.028$ in the score awarded between the 2014 (5.83 points \pm 2.06 [5.52-6.15]
3 95% CI) vs 2015 (6.58 points \pm 1.74 [6.35-6.81] 95% CI) ($P=0.0002$, $d=0.39$) and 2015
4 (6.58 points \pm 1.74 [6.35-6.81] 95% CI) vs 2016 (6.02 points \pm 1.67 [5.79-6.26] 95% CI),
5 ($P=0.006$, $d=0.32$) seasons for the air reverse variation of aerials (Figure 2b). It is further
6 indicated in figure 2b, when the surfer included a full rotation aerial during the 2015
7 season (8.55 points \pm 1.20 [8.05-9.04] 95% CI), they received a significant and moderate
8 increase in score ($P=0.018$, $d=0.76$) as opposed to performing the same aerial in 2014
9 (7.11 points \pm 2.34 [5.69-8.52] 95% CI).

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21 ******FIGURE THREE HERE******
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24 When the surfer performed an aerial on their forehand they were rewarded with a
25 significant and small effect increase in score during 2015 (6.78 points \pm 1.69 [6.59-6.98]
26 95% CI) than in 2016 (6.32 points \pm 1.73 [6.12-6.52] 95% CI) $R^2=0.015$, $F(3,675)=3.426$.
27 $P=0.011$, $d=0.27$. As indicated in figure 3, when comparing the scores for waves
28 performed on the backhand the mean score for 2015 season (6.37 points \pm 2.1 [5.83-6.92]
29 95% CI) was slightly lower, but not statistically different with a trivial effect than the
30 score awarded in 2016 (6.51 points \pm 2.06 [5.81-7.20] 95% CI) $d=0.06$.
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35 It can be observed from figure 4a that there was a significant difference with a small effect
36 $R^2=0.028$, $F(5,1002)=5.856$. $P<0.0001$ $d=0.46$ between scores awarded in 2014 (5.87
37 points \pm 2.27 [5.58-6.17] 95% CI) for performing an aerial as the final manoeuvre, when
38 compared with performing an aerial as a final manoeuvre in 2015 (6.83 points \pm 1.74
39 [6.57-7.09] 95% CI). When we compared the scores for waves that ended with an aerial
40 manoeuvre, the mean score for 2014 was almost one whole point lower than the score
41 awarded in 2015. During the 2015 season, when an aerial was performed earlier in the
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1 wave (6.59 points), they were also rewarded with a higher score than that in 2014 (6.47
2 points). The scores awarded in 2016 were identified to be lower than both 2014 and 2015.
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4 ******FIGURE FOUR HERE******
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7 When we compared 2014 with the 2015 season a significant difference with a small to
8 intermediate effect was indicated for the scores provided when aerials were performed in
9 the first third of the heat (2014 season: 5.86 points \pm 2.23 [5.40-6.32] 95% CI; 2015
10 season: 6.83 \pm 1.79 [6.48-7.19] 95% CI) $R^2=0.028$, $F(8,999)=2.022$. $P=0.0027$ $d=0.48$.
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12 No other differences were observed in the score awarded within and between years, when
13 compared to the timing of the heat. Scores awarded by the judges across the three time
14 variables (Figure 4b) in 2015 were slightly higher.
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25 DISCUSSION

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28 This study aimed to investigate the influence on score awarded when including an aerial
29 manoeuvre during competition. The inclusion of an aerial had a significant influence on
30 the score awarded for the top two scoring waves across all three seasons ($P<0.05$), when
31 compared to those waves which did not include an aerial manoeuvre (Figure 1). This
32 difference of 0.80, 0.81 and 0.49 of a score in 2014, 2015 and 2016 respectively, was
33 considered to have a small effect. Nevertheless, the difference between winning and
34 losing a heat can be determined by a score as small as 0.01. The small, but significant
35 differences can have a large impact on the surfers' ability to progress through a
36 competition and improve their ranking as outlined by Farley and colleagues (2015).
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38 Farley et al (2015) found that the top 10 ranked surfers over the 2013 WCT season scored
39 on average 1.04 more points per wave when compared to lower ranked surfers. Therefore,
40 the inclusion of an aerial and the potential impact it has on scoring appears very important
41 for bridging the gap between lower ranked surfers and the top 10 in elite level surfing
42 athletes. Farley and associates (2015) further outlined that consistency and lower
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1 variability within heat and individual wave score had a positive influence on competitive
2 performance. Meaning that not only the inclusion of an aerial, but the successful
3 performance of the manoeuvre may influence scoring potential.
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6 When the surfer incorporated an aerial into competitive performance, the results of the
7 current study are similar to earlier studies on scoring in competitive surfing by Lundgren
8 and associates (2013; 2014). For the present study however, only the top two scoring
9 waves for each surfer in each heat were analysed with regards to the overall impact of
10 including an aerial manoeuvre during performance. This provided insights as to whether
11 inclusion of an aerial into the performance positively influenced scoring potential, and
12 the surfer's overall competitive performance. It is evident that during competition, both
13 the inclusion and exclusion of an aerial manoeuvre are awarded a large range of scores
14 (Figure 1). However, as previously outlined, the change in scoring criteria and the high
15 risk associated with an aerial manoeuvre (Tesler, 2011) has enabled the judges to reward
16 the surfer who incorporated an aerial in their wave riding repertoire. Therefore, the
17 scoring potential when including an aerial manoeuvre during competitive performance
18 has a positive impact on scoring potential (Lundgren et al., 2013, 2014; Souza et al., 2012;
19 Piter, 2012).
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22 Due to a vast amount of variables associated with surfing (wave formation, type of break,
23 intensity, quality, environment etc.), waves are never the same and therefore, each wave
24 has great influence in the variation and ability to perform manoeuvres and aerial
25 manoeuvres (Lundgren et al, 2014; Peirão, & dos Santos, 2012). For the surfer to create
26 the optimal velocity to leave the wave and perform an aerial manoeuvre, they need to
27 perform the aerial within the steep part of the wave face, close to the pitching lip of the
28 wave (Piter, 2012). This part of the wave is deemed the critical section of the wave, with
29 judges looking for manoeuvres being as close to the pitching part of the wave to satisfy
30 the judging criteria. However, with this steepness in the wave and the speed of the
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1 breaking wave, performing manoeuvres in this part of the wave has been determined to
2 be high risk for completion (Surfing Australia, 2014; International Surfing Association,
3 2015; World Surf League, 2017). Therefore, for the surfer to perform a highly complex
4 manoeuvre, such as an aerial in a critical part of the wave, the successful completion of a
5 high risk aerial manoeuvre fulfils the judges scoring criteria and results in the surfer being
6 rewarded with a higher score.
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12 From the results (Figure 2a) it can be identified that the ability of the surfer to complete
13 an aerial manoeuvre during both the 2014 and 2015 seasons is below 55%. This
14 completion rate is somewhat lower compared to the completion rates of turning
15 manoeuvres, which were found to be above 90% (Lundgren et al., 2014; Souza et al.,
16 2012). This result may indicate that when the surfer performs and completes an aerial
17 manoeuvre, the surfer is rewarded by the judges with a higher score (Figure 1), whilst
18 potentially increasing the chances of that wave counting as one of the surfer's top two
19 scoring waves. An interesting observation made during analysing the 2016 season was
20 that both the straight air (67%) and alley oop (70%) improved markedly in completion
21 rate from the previous two seasons (Figure 2a). Further analysis revealed that 50% of the
22 straight air attempts (6 aerials) were counted within the surfers' top two scoring waves
23 (12 attempts). This information indicates that when the surfer performed this manoeuvre
24 successfully the aerial was possibly rewarded by the judges. This can be further supported
25 by the single Alley Oop with a grab that was successfully performed in 2016. This aerial
26 variation was positively rewarded by the judges with a score of 7.83, which was 1.08
27 points higher than the score provided for those performing the same aerial variation
28 without a grab (n=21 mean=6.75 points) in the same year. However, future studies
29 focussed on judging and award of score would need to be carried out to verify this.
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58 With reference to the difference in variations of aerial types and score awarded there was
59 found to be a significant difference in the scores awarded between seasons for both the
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1 air reverse and full rotation (Figure 2b). Analysis reveals the air reverse variation is the
2 most common form of aerial attempted in competition (Figure 2a) with 2015 being the
3 year that judges rewarded the surfer with higher scores than in both 2014 (0.74 of a point)
4 and 2016 (0.55 of a point). Of the eight other variations, the full rotation which requires
5 a full 360⁰ rotation as opposed to the 180⁰ rotation seen in the air reverse was the only
6 other variation that provided significant results. When comparing the 2014 and 2015
7 seasons for the full rotation (Figure 2b), the score provided in 2015 was 1.3 points higher
8 than 2014 ($P=0.0177$).
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10 Forsyth et al. (2017) suggested that during the final series of the 2015 season, the forehand
11 straight and forehand full rotation were awarded higher scores than the forehand air
12 reverse. However, with the current study and that carried out by Forsyth and associates
13 (2017), aspects such as other manoeuvres performed on the wave, orientation and axis of
14 rotation of the aerial (technical aspects) have not been quantified. These components all
15 impact on the overall wave performance and aesthetics of the aerial manoeuvre. But when
16 considering the 5 key elements of scoring and the inclusion of aerial manoeuvres, judges
17 need to consider the additional 180⁰ rotation within the context of the criteria. By
18 increasing the technical ability of the surfer, this may enable the surfer to add a further
19 dimension to the variation performed increasing their scoring potential. This additional
20 complexity above the lip of the wave also addresses the key judging components of
21 difficulty, commitment, innovation and progression.
22

23 The direction the surfer faced during the wave ride also indicated a seasonal effect with
24 regards to scoring potential. During the 2015 season, the score awarded for aerials
25 performed on the forehand (facing the wave face) were awarded a significantly
26 ($P=0.0113$) greater score than those in 2016 (Figure 3). No difference was seen in the
27 score awarded when the surfer performed an aerial on their backhand for either the 2015
28 and 2016 seasons or when compared to performing an aerial on the forehand. However,
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1 further analysis by Forsyth and associates (2017) during the final series identified for the
2 air reverse manoeuvre in 2015, the backhand attempts were awarded a higher score than
3 forehand attempts. Although this and previous results related to forehand aerials by
4 Forsyth and colleagues (2017) do show a trend in scoring potential, these scores awarded
5 were not significantly different and did not look at the performance leading up to the
6 finals. Furthermore, we cannot make broad based conclusions about the meaningfulness
7 of forehand and backhand aerials and scoring potential, due to methodological reasons
8 that we were not able to overcome. In surfing, a backhand aerial is more difficult for the
9 vast majority of participants, suggesting that this should feature higher in the judging
10 criteria. However, this may also suggest that the forehand airs are better (bigger flight
11 height and time, greater control and grab execution, more dynamic rotation), because the
12 surfers are able to gain better speed and be more precise in their execution.

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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

1 selection of the aerial early in the ride, but that aerials are being performed early in the
2 ride on waves that do not have a very high scoring potential in the first place.
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4 This effect can only be theorised if the aerial performed to finish the wave is deemed to
5 be more influential than the rest of the manoeuvres performed on the wave previously.
6
7 When assessing the key variables for a successful performance of an aerial; speed, height
8 and acrobatic ability and landing (Lundgren et al., 2013; Ferrier et al., 2014), the section
9 of the wave for the performance of this final manoeuvre would then need to be
10 accommodating enough for the surfer to perform the aerial on. But anecdotally, for the
11 surfer to produce the sufficient speed required for the take-off of an aerial manoeuvre,
12 they would then miss prior opportunities for performing other manoeuvres, thus missing
13 potential scoring opportunities and addressing the judging criteria of combination and
14 variety of manoeuvres. This order of performance and where the aerial is placed in the
15 sequence does seem to be an important aspect in the judging criteria and the performance.
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17 However, size of the section of the wave the aerial was performed on and number of
18 previous manoeuvres prior to the aerial would be required to get a better understanding
19 of the impact order and its impact on scoring potential.
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39 In regards to time segment within the heat that the aerial manoeuvre was performed, the
40 results were that the only significant difference in score awarded ($P=0.041$) was between
41 the 2014 and 2015 seasons in the first third of the heat (Figure 4b). Plessner and Haar
42 (2006) outlined that judges tend to use recall from previous scoring opportunities to base
43 their scoring decision upon. Therefore, if judges utilise previous performances for scoring
44 potential, a bias can then become evident, as there is potential for the judge to base the
45 score from memory, and not the performance on its own merits. However, further
46 research into judging and associated scoring is needed.
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1 This finding has implications for the performing surfer and strategies within a heat. If the
2 surfer strategically attempts to incorporate an aerial later in the heat, thinking it will
3 influence the judges, the results show that this is a dangerous strategy to undertake. The
4 findings instead indicate that a surfer should take the opportunity to perform an aerial
5 when, and if, the wave allows the opportunity, with no real bias toward parts of a heat in
6 relation to judging bias or creating a last ditch attempt to sway the judges. This along with
7 where the aerial was performed in the wave sequence would further enhance performance
8 and understanding of influence on score. If the surfer performed multiple manoeuvres and
9 performed the aerial early in the sequence, landing spots like the bottom or the face of the
10 wave would theoretically better enable the surfer to connect additional manoeuvres
11 without losing too much speed or flow. But if they landed effectively in the other areas
12 of the wave, this would mean the surfer would need to negotiate turbulence (white water)
13 or the drop from the top of the wave to then connect to the next part of the wave.
14 Therefore, the importance of the landing spot and the order of the aerial on the wave needs
15 to be better understood to enable the surfer and coach a deeper understanding of the
16 scoring potential.

37 PRACTICAL APPLICATION

38 This study highlights the importance of the inclusion of an aerial manoeuvre in a
39 competitive surfing repertoire and further explains the impact of an aerial on scoring with
40 regards to variation, completion rate, timing and the direction the surfer is facing when
41 performing the aerial manoeuvre. We encourage surfers and coaches to endeavour to
42 incorporate aerial manoeuvres, especially those that comply with the judging criteria.
43 Therefore, those manoeuvres that require a high technical proficiency such as full
44 rotations and alley oop's on both the forehand and backhand have a tendency to be
45 positively rewarded. Therefore, physical preparation and a skills based practice related to
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1 the performance of this manoeuvre in surfing is important to maximise competitive
2 performance. Especially when incorporating the more technically advanced variations
3 such as the full rotation and alley oop variation.
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6 With regards to timing of the manoeuvre, there is no reward seen over the three years
7 with regards to strategy of inclusion of the manoeuvre. Therefore, we encourage the
8 athlete to perform aerial manoeuvres when the wave dynamics allow the manoeuvre to
9 be performed. As strategically incorporating an aerial manoeuvre late in the context of
10 the heat may not be rewarded positively.
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19 CONCLUSION

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22 The results of the present study, in combination with earlier studies by Lundgren et al.
23 (2013; 2014); Peirão and dos Santos (2012), Forsyth et al. (2017) and Ferrier et al. (2014)
24 have all indicated that when a surfer incorporates an aerial into their performance, they
25 will be rewarded with a higher score. When a surfer includes an aerial manoeuvre, our
26 findings suggest the more technical variations such as an aerial reverse and full rotation
27 are rewarded a higher score by the judges. With regards to heat strategy, results suggest
28 there is no benefit to timing an aerial manoeuvre within the heat, or order of performance
29 within a wave. But results do suggest that those aerals performed on the forehand are
30 positively rewarded by the judging panel. Therefore, the authors suggest that a better
31 understanding of the technical aspects to successfully perform an aerial manoeuvre are
32 required to further assess the advent of this manoeuvre and its impact on the competitive
33 aspect of surfing. It is clear however from the findings of this study and previous studies
34 that a surfer's ability to perform an aerial continues to have a positive impact on
35 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)

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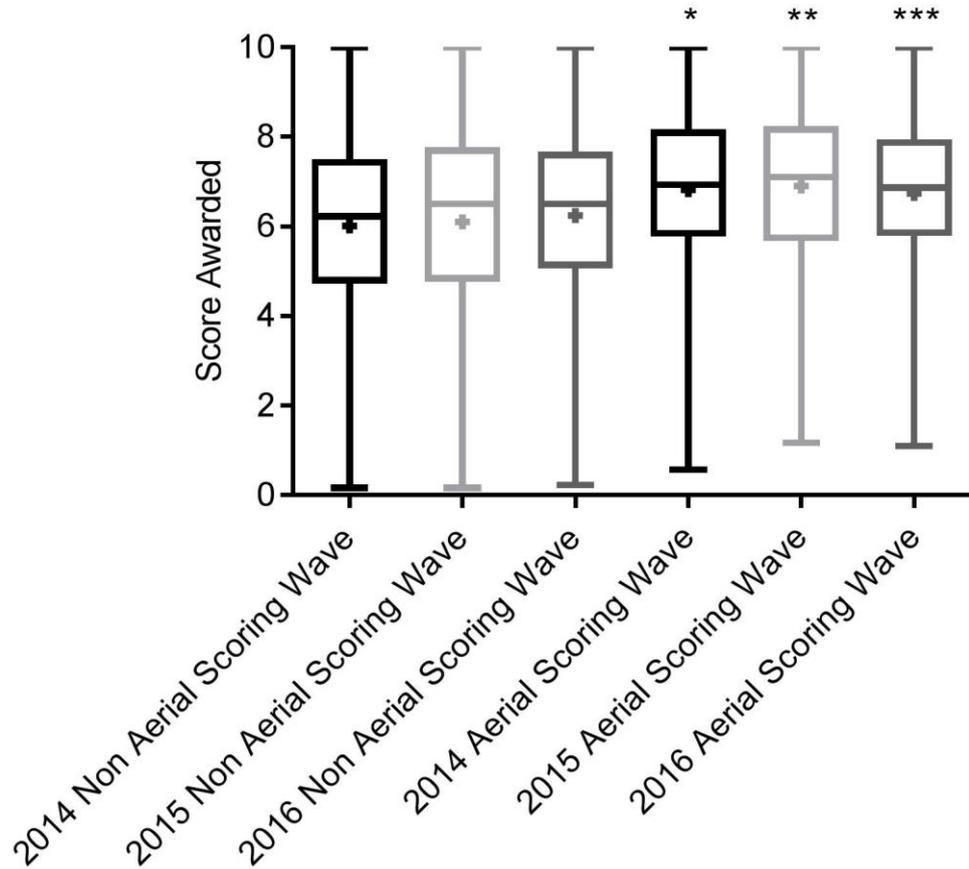


Figure One: Box and whisker plot of comparison of scores awarded to waves which counted as the top two wave scores that included an aerial compared to waves that did not include an aerial during the 2014, 2015 and 2016 WSL competitive season. Centre Line = median, top of box = 75th percentile, bottom 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.

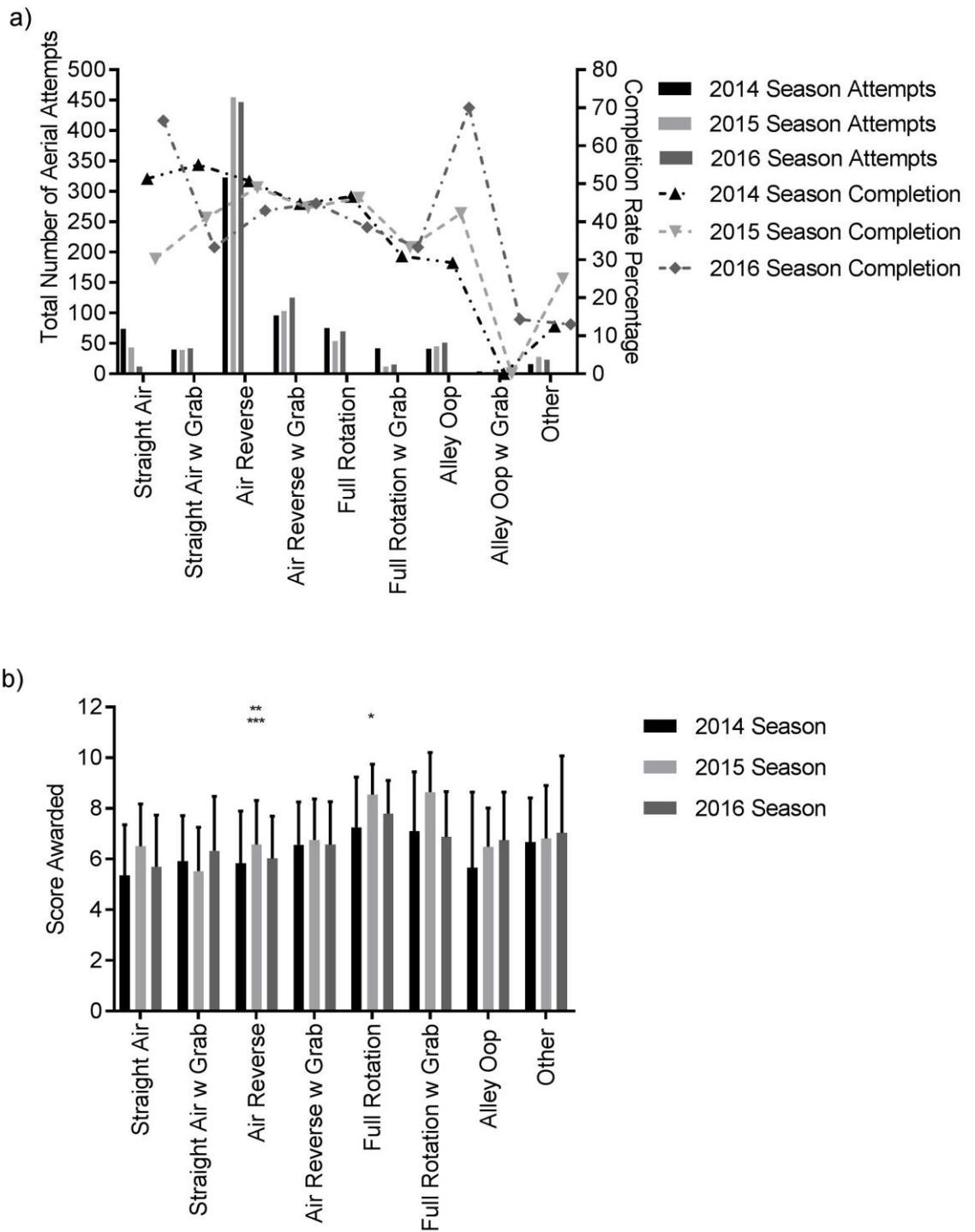


Figure Two: Comparison of aerial variations performed during the 2014, 2015 and 2016 WSL seasons. (a) Descriptive statistics of total number of aerial attempts and the overall completion rate of these attempts and (b) Mean and standard deviation of the scores awarded for the successful completion of 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.

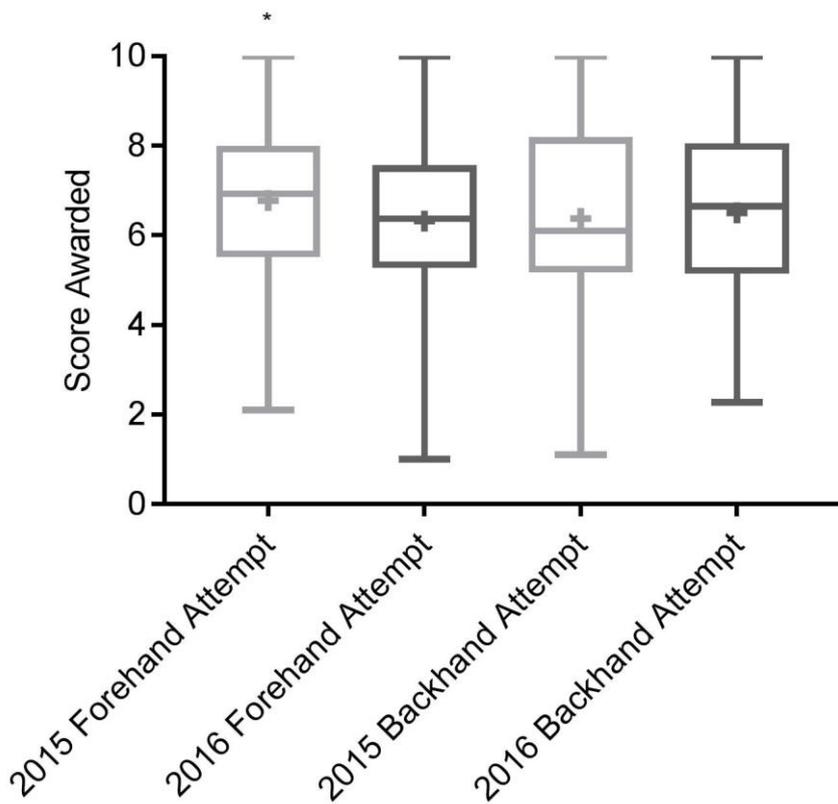


Figure Three: Box and whisker plot of temporal aspects related to the direction the surfer was facing on the wave when the aerial manoeuvre was performed. Centre Line = median, top of box = 75th percentile, bottom of box = 25th percentile, whiskers = data within the range of minimum and maximum score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

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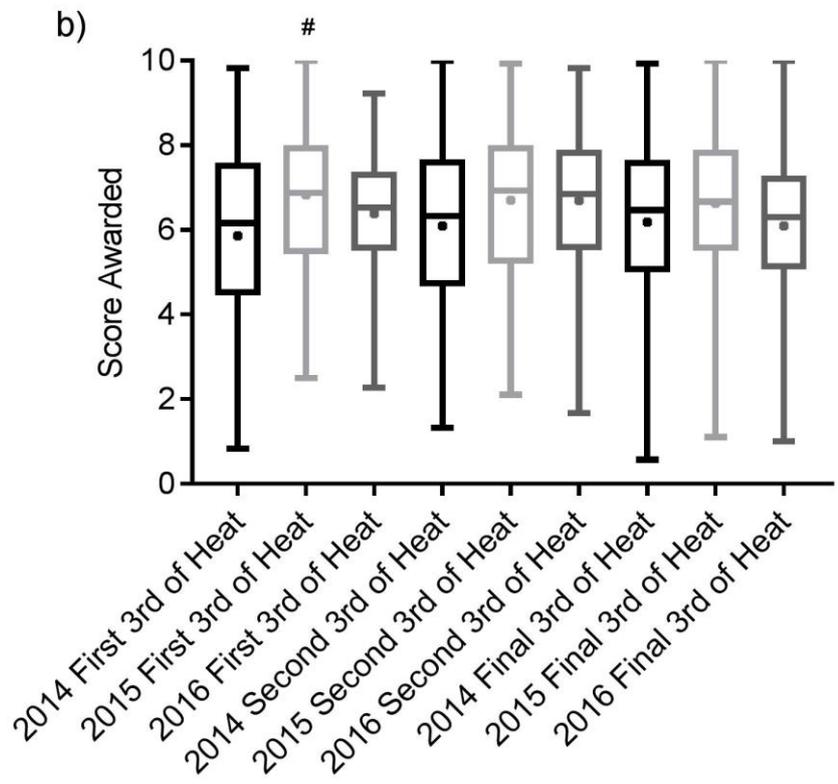
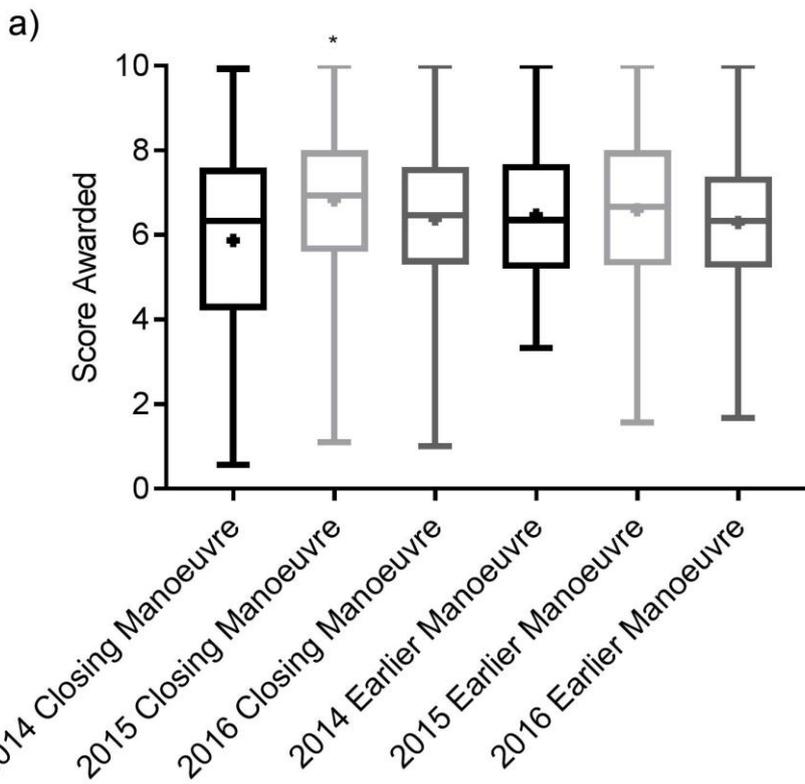


Figure Four: Box and whisker plot of temporal aspects related to when the aerial manoeuvre was performed. (a) Comparison of scores when the aerial manoeuvre was performed as the last move on the wave with performance of the aerial earlier in the sequence of manoeuvres. (b) Comparison of scores awarded 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.

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

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7

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9

10 Word Count: 4365 words (excluding headings and references)

11

12 ABSTRACT

13 The aim of this study was to investigate the impact of aerial manoeuvres on scoring in
14 professional surfing. 23631 waves were analysed for the number and types of aerial
15 manoeuvres performed from the 2014, 2015 and 2016 Men's World Championship Tour.
16 Additionally, the awarded score, timing and order of the aerial was also analysed.
17 Descriptive statistics and Two Way ANOVA's were performed with Sidak Multiple
18 Comparisons Post Hoc analysis. Results were a significantly higher score being awarded
19 ($P \leq 0.0001$) when including an aerial in competition across all three seasons. In 2015
20 surfers were awarded a significantly larger score when performing an air reverse,
21 compared to 2014 ($P=0.0002$) and 2016 ($P=0.0057$). Surfers were also awarded a higher
22 score for the full rotation aerial in 2015 compared to 2014 ($P=0.0177$). In 2015 surfers
23 performing forehand aerials were awarded a greater score than in 2016 ($P=0.0113$). The
24 timing of the aerial and score awarded was significantly greater in 2015 as opposed to
25 2014 when the aerial was their final manoeuvre ($P < 0.0001$) and when surfers timed the
26 aerial performance early within the heat ($P=0.0027$). If a surfer incorporates an aerial
27 manoeuvre during competition, generally speaking, they will be awarded a significantly
28 higher score.

29

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

31

32 INTRODUCTION

33 In competitive surfing, the athlete's performance on each wave surfed is subjectively
34 assessed on a scale of 0-10 points by a panel of 5 accredited judges. The judge's score is
35 based on five key elements: 1) commitment and degree of difficulty; 2) innovative and
36 progressive manoeuvres; 3) combination of major manoeuvres; 4) variety of manoeuvres;
37 and 5) speed, power and flow (World Surf League [WSL], 2014). For a surfer's
38 performance to be awarded a higher score, a combination of manoeuvres that address the
39 5 key elements in the most critical sections of the wave must be performed (Lundgren,
40 Dunn, Nimphius, & Sheppard, 2013; Lundgren, Newton, Tran, Dunn, Nimphius, S, &
41 Sheppard, 2014). The surfer with the highest two-wave total is deemed the winner of the
42 heat. One of the most highly regarded manoeuvres in competitive surfing that has been
43 linked with high performance and high risk is the aerial (Lundgren et al., 2014). The aerial
44 manoeuvre incorporates the surfer launching themselves above the top of the wave then
45 landing back on the same wave to continue their ride (Ferrier, Sheppard, Newton, &
46 Nimphius, 2014).

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

57 Whitting, & Steele (2017) agreed with both previous studies reporting that during the
58 2015 World Championship Tour (WCT), surfers who included an aerial manoeuvre were
59 awarded a significantly greater score than when they just performed manoeuvres on the
60 wave face.

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

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

83 limited published research regarding performance analysis in international competition
84 and how the surfers choice of manoeuvre can influence scoring potential (Ferrier et al.,
85 2014; Forsyth et al., 2017; Lundgren et al., 2013, 2014; Peirão and dos Santos, 2012).

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

96 METHODS

97 All data were recorded for the 33 events carried out during the 2014 (n=11), 2015 (n=11)
98 and 2016 (n=11) Men's WCT, where all waves (n=23631) surfed were analysed. Data
99 collection was carried out between the months February 2014 through February 2017
100 from on-line video content available from the respective events heat analyser function
101 available on the World Surf League website (WSL, 2014). The study and procedures were
102 approved by Edith Cowan University Human Ethics Committee (approval number:
103 10320).

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

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

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

122

123 **Statistical Analysis**

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

134 Magnitude of effect was based on the following criteria: >0.2, trivial; 0.2-0.5, small; 0.5-
135 0.8, medium; and >0.8, large (Cohen, 1988). All statistical analyses were carried out using
136 GraphPad Prism version 7.02 for Windows (GraphPad Software, LaJolla California USA,
137 www.graphpad.com) with statistical significance being set at $P \leq 0.05$.

138 RESULTS

139 As outlined in Figure 1, there was a significant difference between the mean scores of the
140 wave rides that incorporated an aerial manoeuvre (6.82, 6.91, 6.74), versus waves without
141 an aerial (6.01, 6.10, 6.25) in the 2014, 2015 and 2016 seasons respectively $R^2=0.012$,
142 $F(5,7690)=16.86$, $P \leq 0.0001$. Of the 2285 waves analysed that included an aerial, 711
143 aerials were attempted in 2014, 782 were attempted in 2015 and 792 were attempted in
144 2016. The most common variation of aerial attempted over the three years was the air
145 reverse with 323 attempts in 2014, 455 attempts in 2015 and 447 attempts in 2016 (Figure
146 2a).

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

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

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

157 The two way ANOVA indicated a significant and small effect difference $R^2=0.5855$,
158 $F(2,982)=3.028$ in the score awarded between the 2014 (5.83 points \pm 2.06 [5.52-6.15]
159 95% CI) vs 2015 (6.58 points \pm 1.74 [6.35-6.81] 95% CI) ($P=0.0002$, $d=0.39$) and 2015
160 (6.58 points \pm 1.74 [6.35-6.81] 95% CI) vs 2016 (6.02 points \pm 1.67 [5.79-6.26] 95% CI),
161 ($P=0.006$, $d=0.32$) seasons for the air reverse variation of aerials (Figure 2b). It is further
162 indicated in figure 2b, when the surfer included a full rotation aerial during the 2015
163 season (8.55 points \pm 1.20 [8.05-9.04] 95% CI), they received a significant and moderate
164 increase in score ($P=0.018$, $d=0.76$) as opposed to performing the same aerial in 2014
165 (7.11 points \pm 2.34 [5.69-8.52] 95% CI).

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

167 When the surfer performed an aerial on their forehand they were rewarded with a
168 significant and small effect increase in score during 2015 (6.78 points \pm 1.69 [6.59-6.98]
169 95% CI) than in 2016 (6.32 points \pm 1.73 [6.12-6.52] 95% CI) $R^2=0.015$, $F(3,675)=3.426$.
170 $P=0.011$, $d=0.27$. As indicated in figure 3, when comparing the scores for waves
171 performed on the backhand the mean score for 2015 season (6.37 points \pm 2.1 [5.83-6.92]
172 95% CI) was slightly lower, but not statistically different with a trivial effect than the
173 score awarded in 2016 (6.51 points \pm 2.06 [5.81-7.20] 95% CI) $d=0.06$.

174 It can be observed from figure 4a that there was a significant difference with a small effect
175 $R^2=0.028$, $F(5,1002)=5.856$. $P<0.0001$ $d=0.46$ between scores awarded in 2014 (5.87
176 points \pm 2.27 [5.58-6.17] 95% CI) for performing an aerial as the final manoeuvre, when
177 compared with performing an aerial as a final manoeuvre in 2015 (6.83 points \pm 1.74
178 [6.57-7.09] 95% CI). When we compared the scores for waves that ended with an aerial
179 manoeuvre, the mean score for 2014 was almost one whole point lower than the score
180 awarded in 2015. During the 2015 season, when an aerial was performed earlier in the

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

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

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

191 DISCUSSION

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

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

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

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

232 breaking wave, performing manoeuvres in this part of the wave has been determined to
233 be high risk for completion (Surfing Australia, 2014; International Surfing Association,
234 2015; World Surf League, 2017). Therefore, for the surfer to perform a highly complex
235 manoeuvre, such as an aerial in a critical part of the wave, the successful completion of a
236 high risk aerial manoeuvre fulfils the judges scoring criteria and results in the surfer being
237 rewarded with a higher score.

238 From the results (Figure 2a) it can be identified that the ability of the surfer to complete
239 an aerial manoeuvre during both the 2014 and 2015 seasons is below 55%. This
240 completion rate is somewhat lower compared to the completion rates of turning
241 manoeuvres, which were found to be above 90% (Lundgren et al., 2014; Souza et al.,
242 2012). This result may indicate that when the surfer performs and completes an aerial
243 manoeuvre, the surfer is rewarded by the judges with a higher score (Figure 1), whilst
244 potentially increasing the chances of that wave counting as one of the surfer's top two
245 scoring waves. An interesting observation made during analysing the 2016 season was
246 that both the straight air (67%) and alley oop (70%) improved markedly in completion
247 rate from the previous two seasons (Figure 2a). Further analysis revealed that 50% of the
248 straight air attempts (6 aerials) were counted within the surfers' top two scoring waves
249 (12 attempts). This information indicates that when the surfer performed this manoeuvre
250 successfully the aerial was possibly rewarded by the judges. This can be further supported
251 by the single Alley Oop with a grab that was successfully performed in 2016. This aerial
252 variation was positively rewarded by the judges with a score of 7.83, which was 1.08
253 points higher than the score provided for those performing the same aerial variation
254 without a grab (n=21 mean=6.75 points) in the same year. However, future studies
255 focussed on judging and award of score would need to be carried out to verify this.

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

258 air reverse and full rotation (Figure 2b). Analysis reveals the air reverse variation is the
259 most common form of aerial attempted in competition (Figure 2a) with 2015 being the
260 year that judges rewarded the surfer with higher scores than in both 2014 (0.74 of a point)
261 and 2016 (0.55 of a point). Of the eight other variations, the full rotation which requires
262 a full 360⁰ rotation as opposed to the 180⁰ rotation seen in the air reverse was the only
263 other variation that provided significant results. When comparing the 2014 and 2015
264 seasons for the full rotation (Figure 2b), the score provided in 2015 was 1.3 points higher
265 than 2014 ($P=0.0177$).

266 Forsyth et al. (2017) suggested that during the final series of the 2015 season, the forehand
267 straight and forehand full rotation were awarded higher scores than the forehand air
268 reverse. However, with the current study and that carried out by Forsyth and associates
269 (2017), aspects such as other manoeuvres performed on the wave, orientation and axis of
270 rotation of the aerial (technical aspects) have not been quantified. These components all
271 impact on the overall wave performance and aesthetics of the aerial manoeuvre. But when
272 considering the 5 key elements of scoring and the inclusion of aerial manoeuvres, judges
273 need to consider the additional 180⁰ rotation within the context of the criteria. By
274 increasing the technical ability of the surfer, this may enable the surfer to add a further
275 dimension to the variation performed increasing their scoring potential. This additional
276 complexity above the lip of the wave also addresses the key judging components of
277 difficulty, commitment, innovation and progression.

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

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

311 This effect can only be theorised if the aerial performed to finish the wave is deemed to
312 be more influential than the rest of the manoeuvres performed on the wave previously.

313 When assessing the key variables for a successful performance of an aerial; speed, height
314 and acrobatic ability and landing (Lundgren et al., 2013; Ferrier et al., 2014), the section
315 of the wave for the performance of this final manoeuvre would then need to be
316 accommodating enough for the surfer to perform the aerial on. But anecdotally, for the
317 surfer to produce the sufficient speed required for the take-off of an aerial manoeuvre,
318 they would then miss prior opportunities for performing other manoeuvres, thus missing
319 potential scoring opportunities and addressing the judging criteria of combination and
320 variety of manoeuvres. This order of performance and where the aerial is placed in the
321 sequence does seem to be an important aspect in the judging criteria and the performance.
322 However, size of the section of the wave the aerial was performed on and number of
323 previous manoeuvres prior to the aerial would be required to get a better understanding
324 of the impact order and its impact on scoring potential.

325 In regards to time segment within the heat that the aerial manoeuvre was performed, the
326 results were that the only significant difference in score awarded ($P=0.041$) was between
327 the 2014 and 2015 seasons in the first third of the heat (Figure 4b). Plessner and Haar
328 (2006) outlined that judges tend to use recall from previous scoring opportunities to base
329 their scoring decision upon. Therefore, if judges utilise previous performances for scoring
330 potential, a bias can then become evident, as there is potential for the judge to base the
331 score from memory, and not the performance on its own merits. However, further
332 research into judging and associated scoring is needed.

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

349 PRACTICAL APPLICATION

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

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

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

366 CONCLUSION

367 The results of the present study, in combination with earlier studies by Lundgren et al.
368 (2013; 2014); Peirão and dos Santos (2012), Forsyth et al. (2017) and Ferrier et al. (2014)
369 have all indicated that when a surfer incorporates an aerial into their performance, they
370 will be rewarded with a higher score. When a surfer includes an aerial manoeuvre, our
371 findings suggest the more technical variations such as an aerial reverse and full rotation
372 are rewarded a higher score by the judges. With regards to heat strategy, results suggest
373 there is no benefit to timing an aerial manoeuvre within the heat, or order of performance
374 within a wave. But results do suggest that those aerials performed on the forehand are
375 positively rewarded by the judging panel. Therefore, the authors suggest that a better
376 understanding of the technical aspects to successfully perform an aerial manoeuvre are
377 required to further assess the advent of this manoeuvre and its impact on the competitive
378 aspect of surfing. It is clear however from the findings of this study and previous studies
379 that a surfer's ability to perform an aerial continues to have a positive impact on
380 competitive performance and the athlete's ability to score.

381

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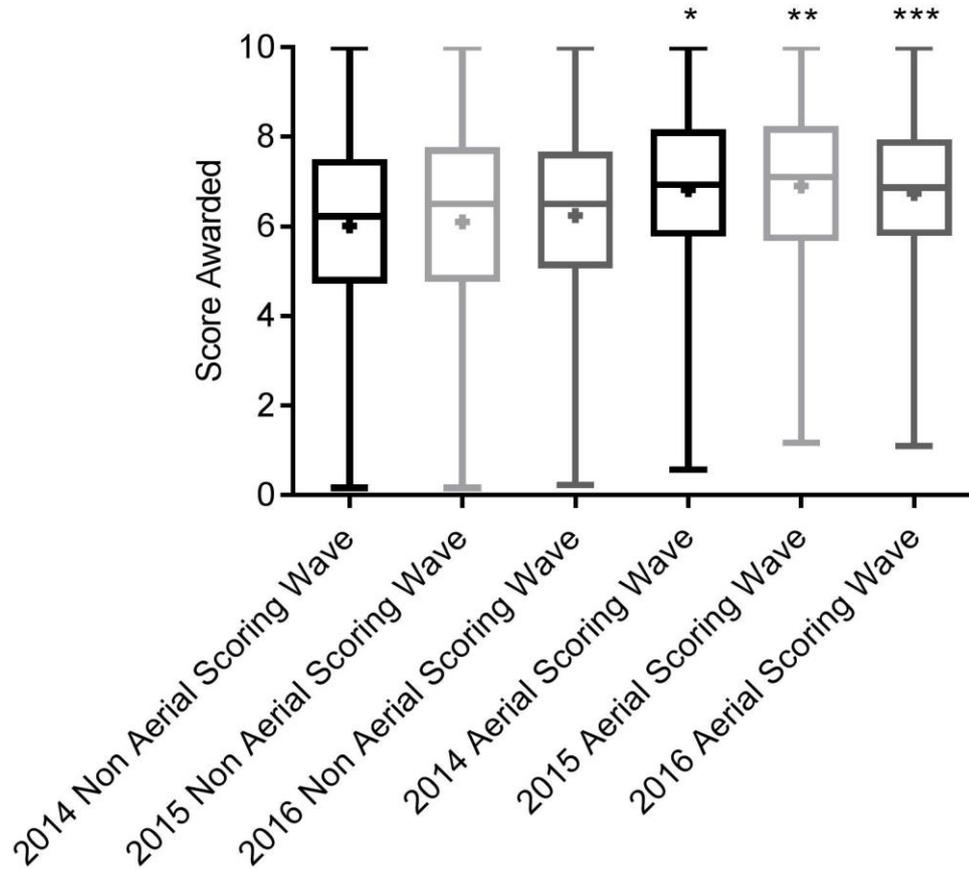
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429 **Table One: Aerial Variation Classification and Definition**

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.

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Piter (2012)

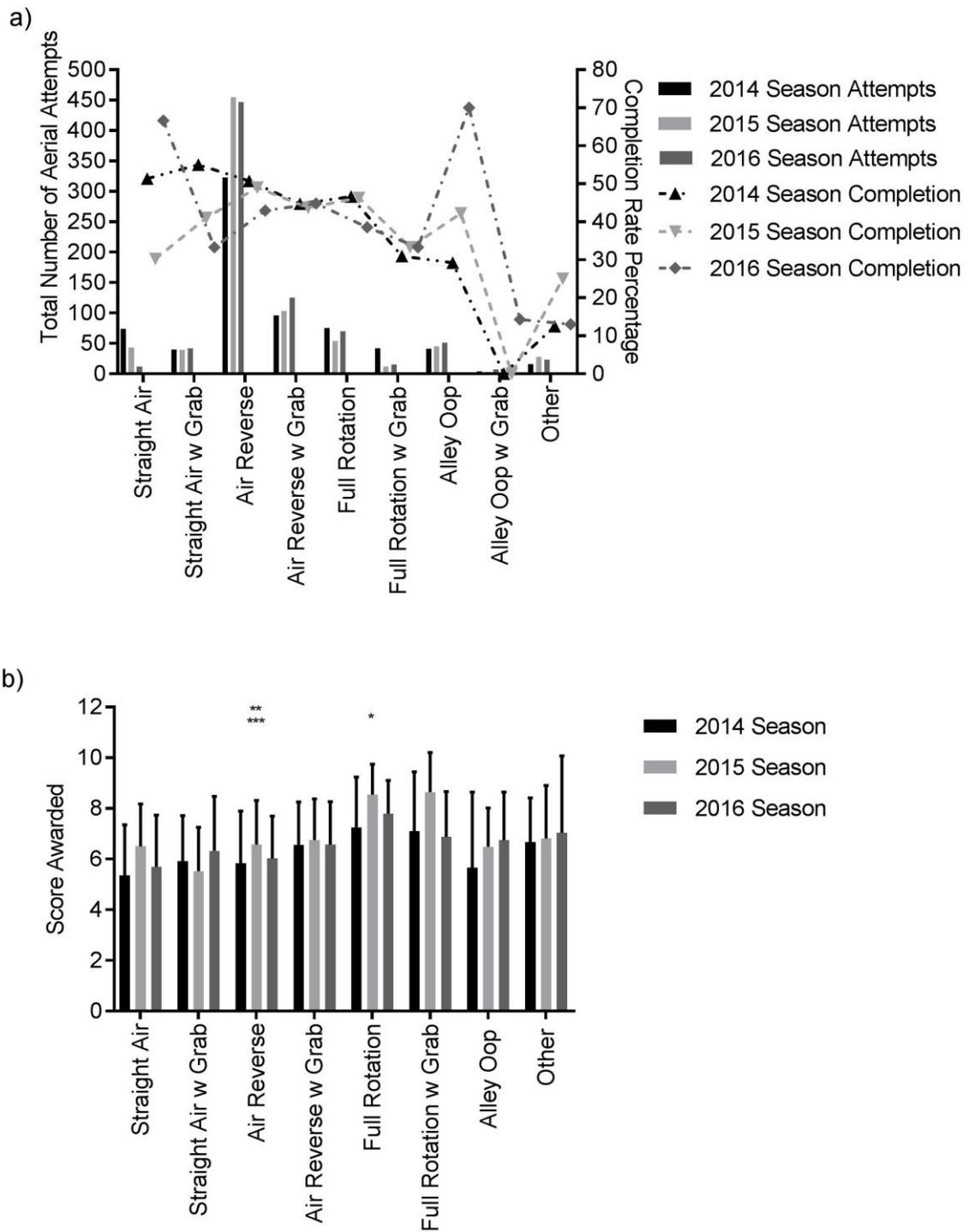


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433 **Figure One:** Box and whisker plot of comparison of scores awarded to waves which counted as the top
 434 two wave scores that included an aerial compared to waves that did not include an aerial during the 2014,
 435 2015 and 2016 WSL competitive season. Centre Line = median, top of box = 75th percentile, bottom of box
 436 = 25th percentile, whiskers = data within the range of minimum and maximum score awarded, + = mean. *
 437 = significant difference ($p < 0.0001$) between 2014 Non Aerial Scoring Wave and 2014 Aerial Scoring
 438 Wave. ** = significant difference ($p < 0.0001$) between 2015 Non Aerial Scoring Wave and 2015 Aerial
 439 Scoring Wave. *** = significant difference ($p = 0.0066$) between 2016 Non Aerial Scoring Wave and 2016
 440 Aerial Scoring Wave.

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444 **Figure Two:** Comparison of aerial variations performed during the 2014, 2015 and 2016 WSL seasons. (a)

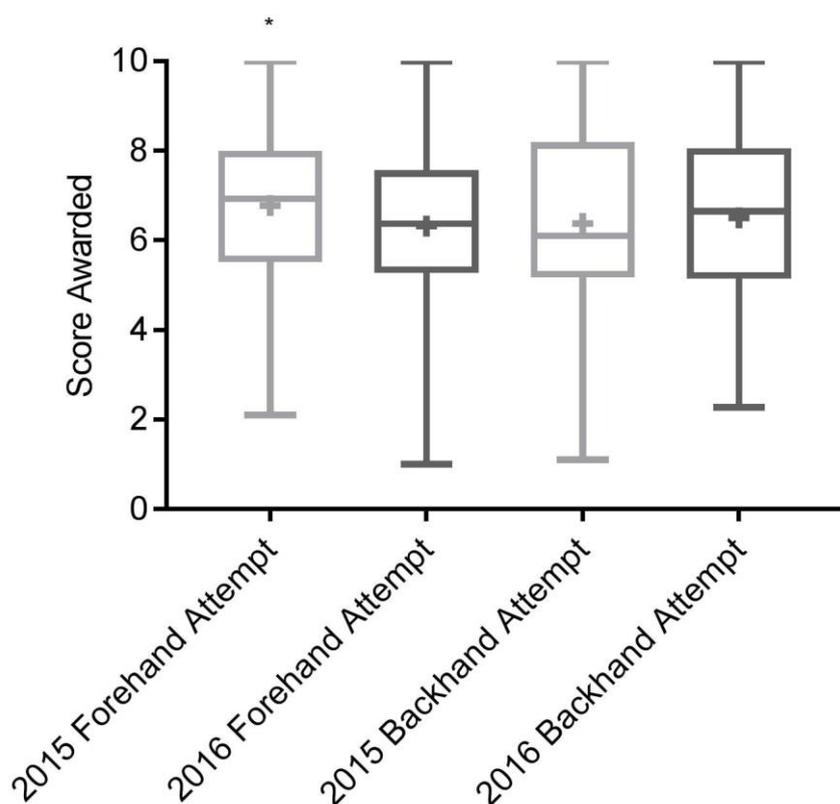
445 Descriptive statistics of total number of aerial attempts and the overall completion rate of these attempts

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

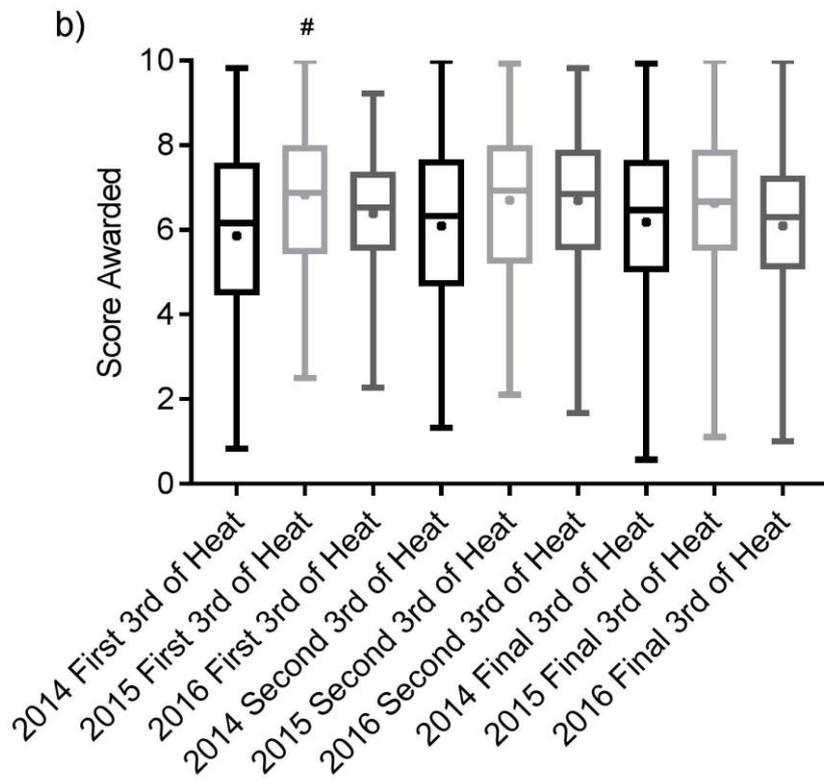
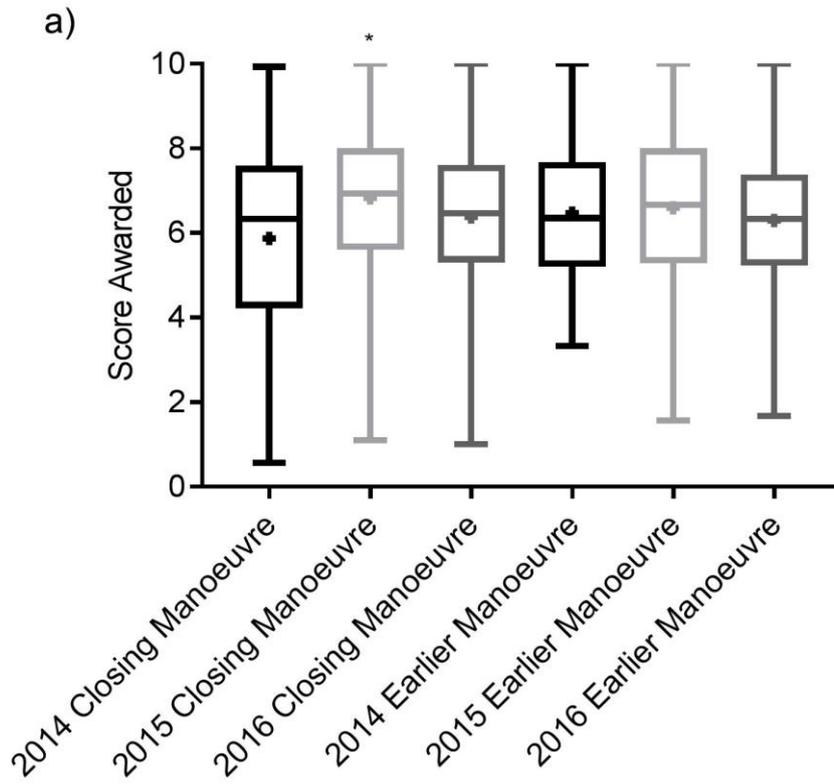
449 for the 2014 Air Reverse and 2015 Air Reverse. *** = significant difference (p=0.0057) between the score
450 awarded for the 2015 Air Reverse and 2016 Air Reverse.



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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).

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

1 Scoring Analysis of the Men's 2014, 2015 and 2016 World
2 Championship Tour of Surfing: The Importance of Aerial
3 Manoeuvres in Competitive Surfing.
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7 Research conducted at Hurley Surfing Australia High Performance Centre
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30 ABSTRACT

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3 31 The aim of this study was to investigate the impact of aerial manoeuvres on scoring in
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5 32 professional surfing. 23631 waves were analysed for the number and types of aerial
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7 33 manoeuvres performed from the 2014, 2015 and 2016 Men’s World Championship Tour.
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10 34 Additionally, the awarded score, timing and order of the aerial was also analysed.
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12 35 Descriptive statistics and Two Way ANOVA’s were performed with Sidak Multiple
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14 36 Comparisons Post Hoc analysis. Results were a significantly higher score being awarded
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17 37 ($P \leq 0.0001$) when including an aerial in competition across all three seasons. In 2015
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19 38 surfers were awarded a significantly larger score when performing an air reverse,
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22 39 compared to 2014 ($P=0.0002$) and 2016 ($P=0.0057$). Surfers were also awarded a higher
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24 40 score for the full rotation aerial in 2015 compared to 2014 ($P=0.0177$). In 2015 surfers
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26 41 performing forehand aerials were awarded a greater score than in 2016 ($P=0.0113$). The
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29 42 timing of the aerial and score awarded was significantly greater in 2015 as opposed to
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32 43 2014 when the aerial was their final manoeuvre ($P < 0.0001$) and when surfers timed the
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34 44 aerial performance early within the heat ($P=0.0027$). If a surfer incorporates an aerial
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36 45 manoeuvre during competition, generally speaking, they will be awarded a significantly
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39 46 higher score.

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45 48 **Keywords:** Notational Analysis, Performance, Awarded Score, Coaching Impact
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50 INTRODUCTION

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3 51 In competitive surfing, the athlete's performance on each wave surfed is subjectively
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5 52 assessed on a scale of 0-10 points by a panel of 5 accredited judges. The judge's score is
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7 53 based on five key elements: 1) commitment and degree of difficulty; 2) innovative and
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10 54 progressive manoeuvres; 3) combination of major manoeuvres; 4) variety of manoeuvres;
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12 55 and 5) speed, power and flow (World Surf League [WSL], 2014). For a surfer's
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14 56 performance to be awarded a higher score, a combination of manoeuvres that address the
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17 57 5 key elements in the most critical sections of the wave must be performed (Lundgren,
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19 58 Dunn, Nimphius, & Sheppard, 2013; Lundgren, Newton, Tran, Dunn, Nimphius, &
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22 59 Sheppard, 2014). The surfer with the highest two-wave total is deemed the winner of the
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24 60 heat. One of the most highly regarded manoeuvres in competitive surfing that has been
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27 61 linked with high performance and high risk is the aerial (Lundgren et al., 2014). The aerial
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29 62 manoeuvre incorporates the surfer launching themselves above the top of the wave then
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32 63 landing back on the same wave to continue their ride (Ferrier, Sheppard, Newton, &
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34 64 Nimphius, 2014).

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37 65 The importance of the inclusion of an aerial manoeuvre was highlighted previously by
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39 66 Peirão and dos Santos (2012) during two Association of Surfing Professionals (ASP)
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42 67 competitions in 2007 and 2010. The study reported that the performance of an aerial
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44 68 manoeuvre when incorporated with a series of other manoeuvres had a low but significant
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47 69 correlation ($r = 0.30$; $P \leq 0.001$) with wave score. Additionally, our research team
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49 70 (Lundgren et al., 2014) also reported that surfers including an aerial manoeuvre during
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52 71 competitions were awarded an average score of 7.40 (± 1.53) out of 10. In comparison,
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54 72 the same study highlighted that rides not including an aerial were on average, awarded a
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57 73 significantly lower ($P < 0.001$) score of 5.08 (± 2.21) during the 2012 ASP World
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59 74 Championship Tour. A recent study by Forsyth, de la Harpe, Riddiford-Harland,

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75 Whitting, & Steele (2017) agreed with both previous studies reporting that during the
76 2015 World Championship Tour (WCT), surfers who included an aerial manoeuvre were
77 awarded a significantly greater score than when they just performed manoeuvres on the
78 wave face.

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

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

101 limited published research regarding performance analysis in international competition
102 and how the surfers choice of manoeuvre can influence scoring potential (Ferrier et al.,
103 2014; Forsyth et al., 2017; Lundgren et al., 2013, 2014; Peirão and dos Santos, 2012).

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

114 METHODS

115 All data were recorded for the 33 events carried out during the 2014 (n=11), 2015 (n=11)
116 and 2016 (n=11) Men's WCT, where all waves (n=23631) surfed were analysed. Data
117 collection was carried out between the months February 2014 through February 2017
118 from on-line video content available from the respective events heat analyser function
119 available on the World Surf League website (WSL, 2014). The study and procedures were
120 approved by Edith Cowan University Human Ethics Committee (approval number:
121 10320).

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

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

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

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141 **Statistical Analysis**

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

152 Magnitude of effect was based on the following criteria: >0.2, trivial; 0.2-0.5, small; 0.5-
153 0.8, medium; and >0.8, large (Cohen, 1988). All statistical analyses were carried out using
154 GraphPad Prism version 7.02 for Windows (GraphPad Software, LaJolla California USA,
155 www.graphpad.com) with statistical significance being set at $P \leq 0.05$.

156 RESULTS

157 As outlined in Figure 1, there was a significant difference between the mean scores of the
158 wave rides that incorporated an aerial manoeuvre (6.82, 6.91, 6.74), versus waves without
159 an aerial (6.01, 6.10, 6.25) in the 2014, 2015 and 2016 seasons respectively $R^2=0.012$,
160 $F(5,7690)=16.86$, $P \leq 0.0001$. Of the 2285 waves analysed that included an aerial, 711
161 aerials were attempted in 2014, 782 were attempted in 2015 and 792 were attempted in
162 2016. The most common variation of aerial attempted over the three years was the air
163 reverse with 323 attempts in 2014, 455 attempts in 2015 and 447 attempts in 2016 (Figure
164 2a).

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

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

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

175 The two way ANOVA indicated a significant and small effect difference $R^2=0.5855$,
176 $F(2,982)=3.028$ in the score awarded between the 2014 (5.83 points \pm 2.06 [5.52-6.15]
177 95% CI) vs 2015 (6.58 points \pm 1.74 [6.35-6.81] 95% CI) ($P=0.0002$, $d=0.39$) and 2015
178 (6.58 points \pm 1.74 [6.35-6.81] 95% CI) vs 2016 (6.02 points \pm 1.67 [5.79-6.26] 95% CI),
179 ($P=0.006$, $d=0.32$) seasons for the air reverse variation of aerials (Figure 2b). It is further
180 indicated in figure 2b, when the surfer included a full rotation aerial during the 2015
181 season (8.55 points \pm 1.20 [8.05-9.04] 95% CI), they received a significant and moderate
182 increase in score ($P=0.018$, $d=0.76$) as opposed to performing the same aerial in 2014
183 (7.11 points \pm 2.34 [5.69-8.52] 95% CI).

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

185 When the surfer performed an aerial on their forehand they were rewarded with a
186 significant and small effect increase in score during 2015 (6.78 points \pm 1.69 [6.59-6.98]
187 95% CI) than in 2016 (6.32 points \pm 1.73 [6.12-6.52] 95% CI) $R^2=0.015$, $F(3,675)=3.426$.
188 $P=0.011$, $d=0.27$. As indicated in figure 3, when comparing the scores for waves
189 performed on the backhand the mean score for 2015 season (6.37 points \pm 2.1 [5.83-6.92]
190 95% CI) was slightly lower, but not statistically different with a trivial effect than the
191 score awarded in 2016 (6.51 points \pm 2.06 [5.81-7.20] 95% CI) $d=0.06$.

192 It can be observed from figure 4a that there was a significant difference with a small effect
193 $R^2=0.028$, $F(5,1002)=5.856$. $P<0.0001$ $d=0.46$ between scores awarded in 2014 (5.87
194 points \pm 2.27 [5.58-6.17] 95% CI) for performing an aerial as the final manoeuvre, when
195 compared with performing an aerial as a final manoeuvre in 2015 (6.83 points \pm 1.74
196 [6.57-7.09] 95% CI). When we compared the scores for waves that ended with an aerial
197 manoeuvre, the mean score for 2014 was almost one whole point lower than the score
198 awarded in 2015. During the 2015 season, when an aerial was performed earlier in the

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

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

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

209 DISCUSSION

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

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

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

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

250 breaking wave, performing manoeuvres in this part of the wave has been determined to
251 be high risk for completion (Surfing Australia, 2014; International Surfing Association,
252 2015; World Surf League, 2017). Therefore, for the surfer to perform a highly complex
253 manoeuvre, such as an aerial in a critical part of the wave, the successful completion of a
254 high risk aerial manoeuvre fulfils the judges scoring criteria and results in the surfer being
255 rewarded with a higher score.

256 From the results (Figure 2a) it can be identified that the ability of the surfer to complete
257 an aerial manoeuvre during both the 2014 and 2015 seasons is below 55%. This
258 completion rate is somewhat lower compared to the completion rates of turning
259 manoeuvres, which were found to be above 90% (Lundgren et al., 2014; Souza et al.,
260 2012). This result may indicate that when the surfer performs and completes an aerial
261 manoeuvre, the surfer is rewarded by the judges with a higher score (Figure 1), whilst
262 potentially increasing the chances of that wave counting as one of the surfer's top two
263 scoring waves. An interesting observation made during analysing the 2016 season was
264 that both the straight air (67%) and alley oop (70%) improved markedly in completion
265 rate from the previous two seasons (Figure 2a). Further analysis revealed that 50% of the
266 straight air attempts (6 aerials) were counted within the surfers' top two scoring waves
267 (12 attempts). This information indicates that when the surfer performed this manoeuvre
268 successfully the aerial was possibly rewarded by the judges. This can be further supported
269 by the single Alley Oop with a grab that was successfully performed in 2016. This aerial
270 variation was positively rewarded by the judges with a score of 7.83, which was 1.08
271 points higher than the score provided for those performing the same aerial variation
272 without a grab (n=21 mean=6.75 points) in the same year. However, future studies
273 focussed on judging and award of score would need to be carried out to verify this.

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

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276 air reverse and full rotation (Figure 2b). Analysis reveals the air reverse variation is the
277 most common form of aerial attempted in competition (Figure 2a) with 2015 being the
278 year that judges rewarded the surfer with higher scores than in both 2014 (0.74 of a point)
279 and 2016 (0.55 of a point). Of the eight other variations, the full rotation which requires
280 a full 360⁰ rotation as opposed to the 180⁰ rotation seen in the air reverse was the only
281 other variation that provided significant results. When comparing the 2014 and 2015
282 seasons for the full rotation (Figure 2b), the score provided in 2015 was 1.3 points higher
283 than 2014 ($P=0.0177$).

284 Forsyth et al. (2017) suggested that during the final series of the 2015 season, the forehand
285 straight and forehand full rotation were awarded higher scores than the forehand air
286 reverse. However, with the current study and that carried out by Forsyth and associates
287 (2017), aspects such as other manoeuvres performed on the wave, orientation and axis of
288 rotation of the aerial (technical aspects) have not been quantified. These components all
289 impact on the overall wave performance and aesthetics of the aerial manoeuvre. But when
290 considering the 5 key elements of scoring and the inclusion of aerial manoeuvres, judges
291 need to consider the additional 180⁰ rotation within the context of the criteria. By
292 increasing the technical ability of the surfer, this may enable the surfer to add a further
293 dimension to the variation performed increasing their scoring potential. This additional
294 complexity above the lip of the wave also addresses the key judging components of
295 difficulty, commitment, innovation and progression.

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

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

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

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

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

343 In regards to time segment within the heat that the aerial manoeuvre was performed, the
344 results were that the only significant difference in score awarded ($P=0.041$) was between
345 the 2014 and 2015 seasons in the first third of the heat (Figure 4b). Plessner and Haar
346 (2006) outlined that judges tend to use recall from previous scoring opportunities to base
347 their scoring decision upon. Therefore, if judges utilise previous performances for scoring
348 potential, a bias can then become evident, as there is potential for the judge to base the
349 score from memory, and not the performance on its own merits. However, further
350 research into judging and associated scoring is needed.

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

367 PRACTICAL APPLICATION

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

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

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

384 CONCLUSION

385 The results of the present study, in combination with earlier studies by Lundgren et al.
386 (2013; 2014); Peirão and dos Santos (2012), Forsyth et al. (2017) and Ferrier et al. (2014)
387 have all indicated that when a surfer incorporates an aerial into their performance, they
388 will be rewarded with a higher score. When a surfer includes an aerial manoeuvre, our
389 findings suggest the more technical variations such as an aerial reverse and full rotation
390 are rewarded a higher score by the judges. With regards to heat strategy, results suggest
391 there is no benefit to timing an aerial manoeuvre within the heat, or order of performance
392 within a wave. But results do suggest that those aerials performed on the forehand are
393 positively rewarded by the judging panel. Therefore, the authors suggest that a better
394 understanding of the technical aspects to successfully perform an aerial manoeuvre are
395 required to further assess the advent of this manoeuvre and its impact on the competitive
396 aspect of surfing. It is clear however from the findings of this study and previous studies
397 that a surfer's ability to perform an aerial continues to have a positive impact on
398 competitive performance and the athlete's ability to score.

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444 <http://www.worldsurfleague.com/events?tourGroupCode=ct&year=2014>

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447 **Table One: Aerial Variation Classification and Definition**

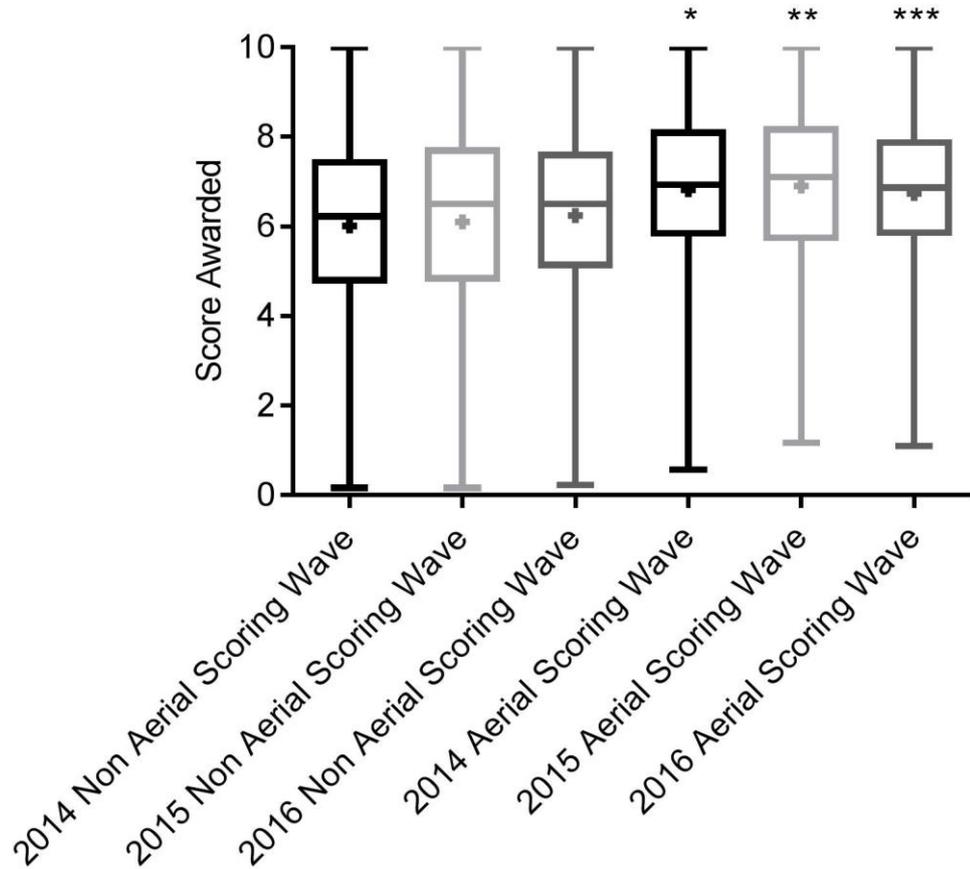
Aerial Variation	Definition
Straight	Where the board and rider are projected above the lip line of the wave with no rotation
Straight with Grab	As above, however the surfer grabs the rail of the board whilst in the air
Air Reverse	Where the rider and board rotate forward at least 180 degrees whilst in 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.

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Piter (2012)

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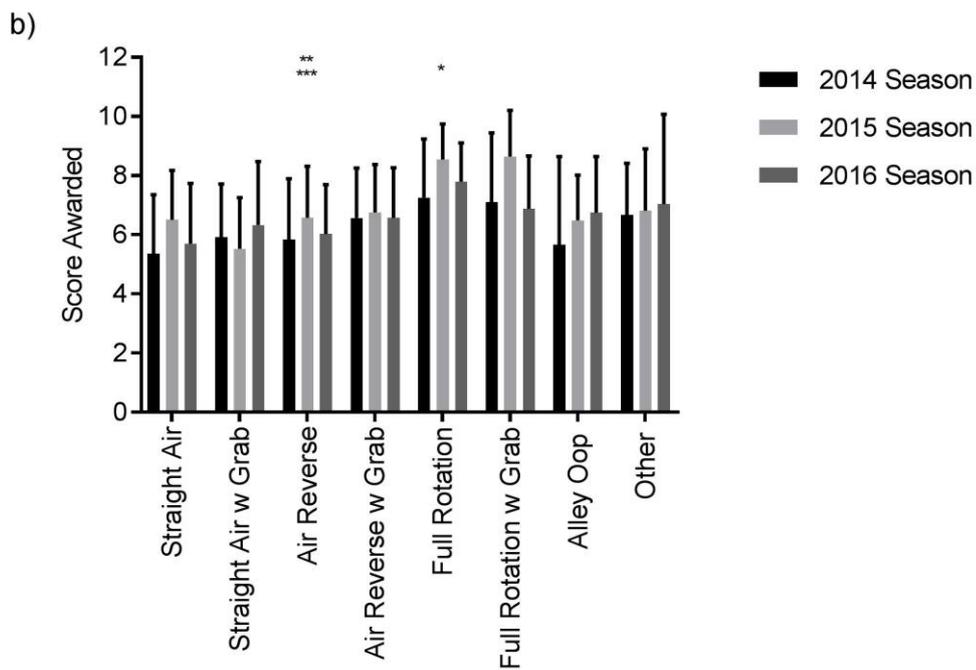
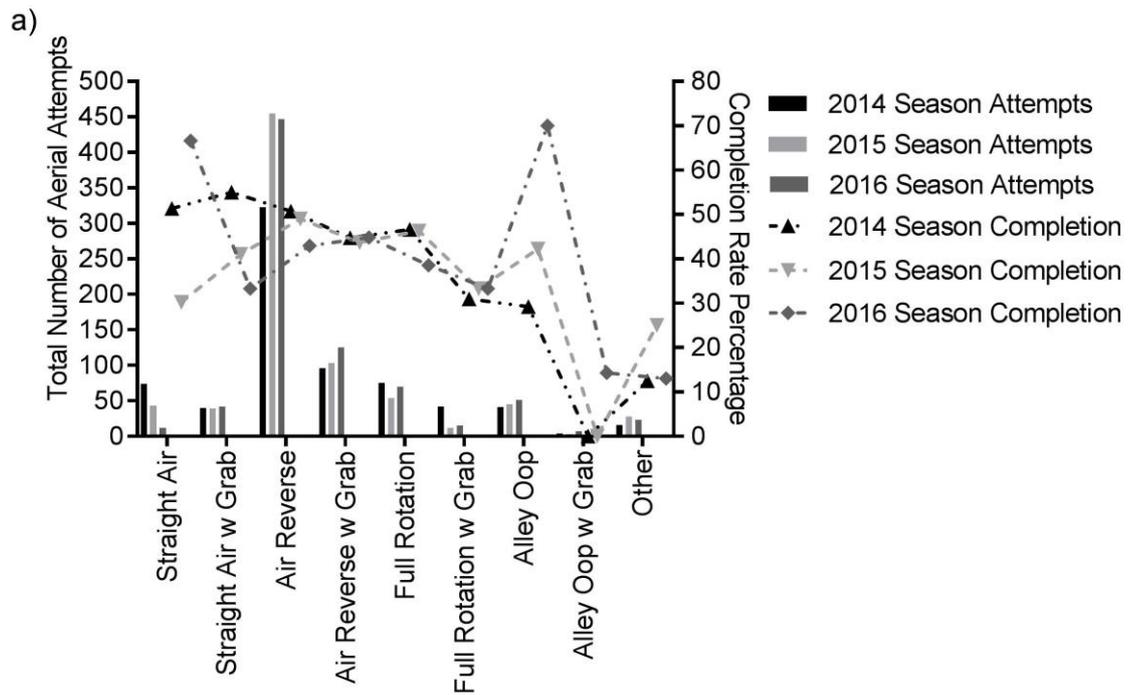


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451 **Figure One:** Box and whisker plot of comparison of scores awarded to waves which counted as the top
452 two wave scores that included an aerial compared to waves that did not include an aerial during the 2014,
453 2015 and 2016 WSL competitive season. Centre Line = median, top of box =75th percentile, bottom of box
454 = 25th percentile, whiskers = data within the range of minimum and maximum score awarded, + = mean. *
455 = significant difference (p<0.0001) between 2014 Non Aerial Scoring Wave and 2014 Aerial Scoring
456 Wave. ** = significant difference (p<0.0001) between 2015 Non Aerial Scoring Wave and 2015 Aerial
457 Scoring Wave. *** = significant difference (p=0.0066) between 2016 Non Aerial Scoring Wave and 2016
458 Aerial Scoring Wave.

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462 **Figure Two:** Comparison of aerial variations performed during the 2014, 2015 and 2016 WSL seasons. (a)

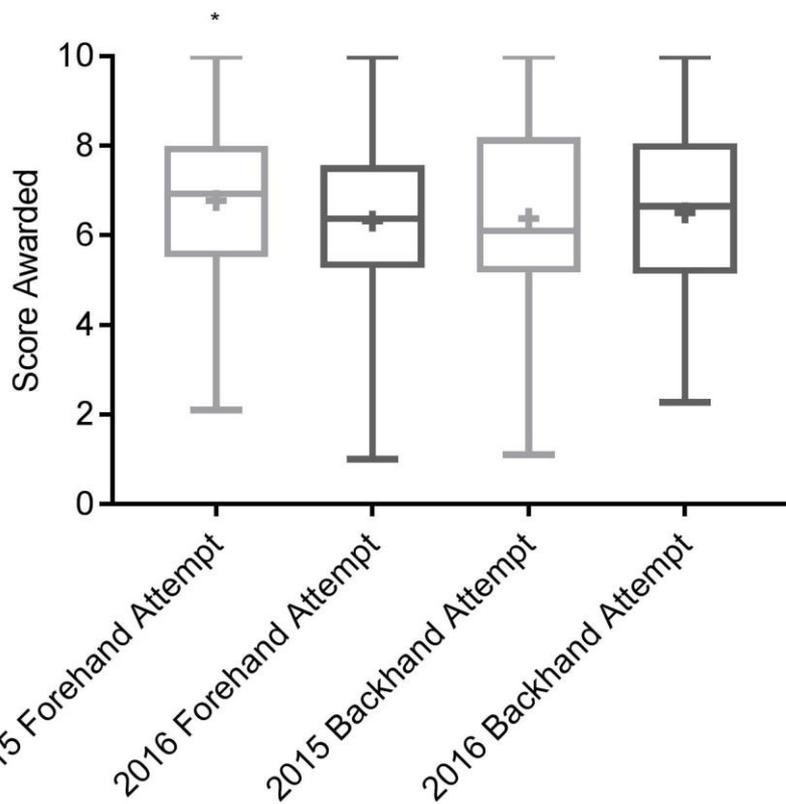
463 Descriptive statistics of total number of aerial attempts and the overall completion rate of these attempts

464 and (b) Mean and standard deviation of the scores awarded for the successful completion of 8 aerial

465 variations. * = significant difference (p=0.0177) between the score awarded for the 2014 Full Rotation

466 Aerial and 2015 Full Rotation Aerial. ** = significant difference (p=0.0002) between the score awarded

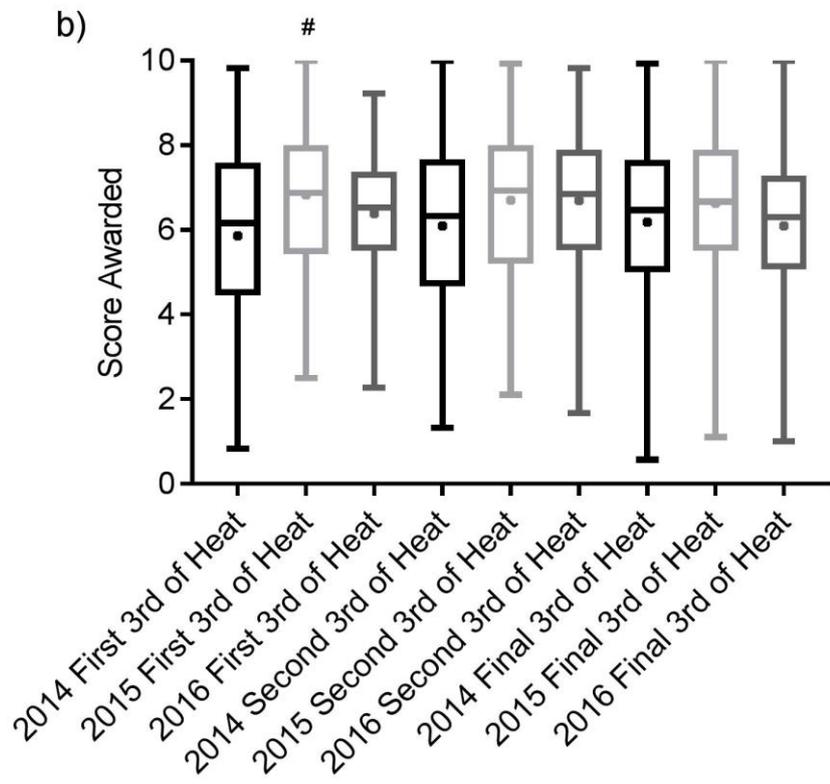
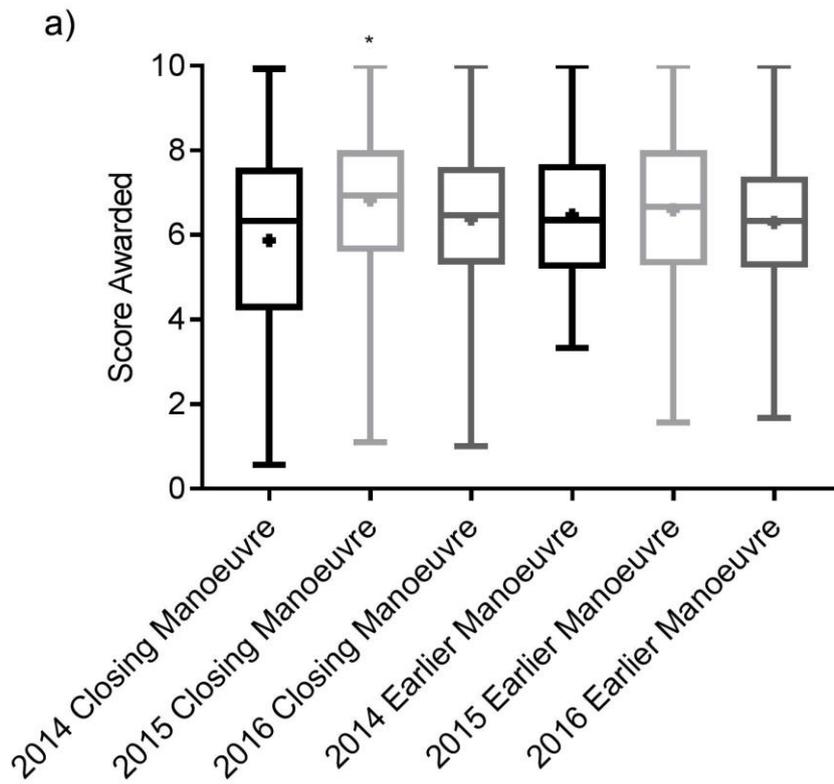
467 for the 2014 Air Reverse and 2015 Air Reverse. *** = significant difference (p=0.0057) between the score
468 awarded for the 2015 Air Reverse and 2016 Air Reverse.



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

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