

# Comparison of amateur boxing before and after the 2013 rules change and the impact on boxers' safety

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## ABSTRACT

**Objectives** The effect of the rules change in 2013 on amateur boxing strategy, technique and safety in comparison with pre-2013 is unknown.

**Methods** Pre-2013 and post-2013 3×3 min elite level amateur boxing was compared from video footage of 29 Olympic (pre-2013) and 50 World Championship bouts (post-2013) totalling 99 male boxers (mean±SD) age: 24.3±3.2 years, height: 177.3±11.3 cm and body mass: 70.7±16.4 kg.

**Result** Many techniques that were dominant pre-2013 were used less post-2013, including: total punches thrown, rear hand punches, hook rear hand, punches landed, uppercut punches, total punches to the body (all <0.05), while movement around the ring and defensive movements were higher post-2013 (both  $p<0.004$ ). Post-2013 boxers have increased their foot movement by 20% to move in and then away from their opponent, combined with long-range punches and deliberate defensive movements. The percentage of rounds where standing counts were issued changed from 9% to 3% pre-2013 to post-2013. However, pre-2013, 1.7% of bouts did not last the full duration due to referee stoppage, while post-2013, this increased to 4.2% as a result of two knockouts and eight technical knockouts.

**Discussion and conclusion** Boxers should be aware of the large changes in technical demands of boxing. An increased risk of concussive or traumatic brain injury post-2013 is equivocal. However, an increase in skin splits and technical knockouts is apparent. It is likely that boxers believe head guard removal has made them more prone to knockouts.

## INTRODUCTION

In 2013, the Amateur International Boxing Association (AIBA) made several substantial changes to the rules of elite male amateur boxing. These included head guards are no longer permitted, 10 oz gloves are to be worn by boxers weighing <152 lbs and 12 oz gloves if heavier, when competing in the Olympics boxers are now allowed to have <16 professional bouts, and scoring is based on professional boxing's 10-point must system.<sup>1,2</sup> Judges 'must' award 10 points to at least one boxer in each round, which normally results in a 10-9 score, the higher score for the boxer that the judges believe won. Further deductions can be made, for incidents such as fouls.<sup>1,2</sup> Pre-2013, the winner was based on landed punches; judges now decide based on four criteria: number of quality punches landed in the target area, domination of the bout by technical and tactical superiority, competitiveness and infringement of the rules.<sup>1</sup>

Recent studies have looked at various formats of amateur boxing, with an aim to understand the demands of the sport and what makes winners, winners. Previous studies have observed: 3×2 min novice males,<sup>3</sup> 3×3 min elite males,<sup>4</sup> 4×2 min elite females<sup>5</sup> and 4×2 min national-level Bosnian males.<sup>6</sup> Most recently observations from bouts after the 2013 rule changes were published highlighting the new demands of the sport.<sup>7</sup> However, accurate information detailing what effect on strategy, technique and safety these changes have had in comparison with pre-2013 boxing are not available. Previous changes in rules and format have affected parameters such as: type and number of punches, punch combinations, movement around the ring and activity rates.<sup>3,5-8</sup>

The introduction of head guards in boxing in 1984 was a reaction to a threat from The American Medical Association to ban amateur boxing from the USA<sup>9,10</sup> However, there was no scientific evidence presented to demonstrate their effect on boxer safety or ability to reduce injury. Even today, little evidence exists of their ability to reduce injury. Furthermore, there is no regulation on their capacity to attenuate rotational punch forces, which are believed to be responsible for concussive and traumatic brain injury.<sup>11-13</sup> Head guard-related concerns have appeared: they make the head bigger and therefore easier to hit, they limit peripheral vision and their weight and unknown force attenuation could create more momentum once a punch has landed.<sup>10</sup> Although contradictory to the previous point, it is also thought that if head guards do dissipate force, it could lead to boxers sustaining repeated impacts for a longer time as opposed to receiving a non-dissipated punch that may end a bout straightaway.<sup>14</sup>

Therefore, we aimed to compare elite male amateur boxing, pre-2013 and post-2013 to quantify the effect of the rules change on bout strategy and technique. This was achieved by comparing the only comparable pre-2013 and post-2013 boxing data available.<sup>4,7</sup> This will allow training and bout strategy to be adapted to current bout demands. Second, an analysis of knockouts, knockdowns and injuries may suggest whether there has been an effect on boxer safety.

## METHODS

### Participants

From the pre-2013 bouts, our study group consisted of 39 elite male boxers (mean±SD), age: 25.1±3.6 years, height: 178.3±10.4 cm, body mass: 69.7±16.5 kg, competing over 10 final and 19 semifinal bouts of the 2012 London Olympic Games. The post-2013 boxer group consisted of 60



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elite males, age:  $23.5 \pm 2.8$  years, height:  $176.2 \pm 12.2$  cm, body mass:  $71.7 \pm 16.2$  kg, competing over 10 final 20 semifinal and 20 quarterfinal bouts of the 2015 Doha World Championships.

Both groups included boxers from all 10 weight categories. The quarter, semifinal and final bouts were chosen to represent the highest quality boxers. Due to the elimination nature of the competitions, some boxers were analysed in more than one bout, for example, a semifinal and a final bout. Both groups of boxers were of a comparable level competing at the highest level (open class) and internationally. All boxers in the 2015 World Championships had also qualified through the continental championships. Furthermore, the Doha 2015 World Championship acted as a selection pool for the 2016 Rio Olympics and so the majority of boxers in the final and semifinal bouts also competed at those Olympics. This enabled accurate comparison between the two studies. The study conformed to the 2013 Declaration of Helsinki and was approved by the local ethics committee.

### Procedures

The bouts were analysed in high definition using Windows Media Player in slow motion replay, which is adjustable in 0.1 s increments, allowing accurate viewing. The footage was originally recorded by the television cameras of a broadcasting company and was obtained from the official AIBA channel on the internet.<sup>15</sup> Two cameras were placed in opposite corners of the ring and one other camera further away to the side of the ring in an elevated position. Due to the large number of parameters being recorded and the fast succession of movements in boxing, a simplistic hand-tally method was used for data collection. Data were recorded for both boxers in each bout. To avoid inter-rater error, all bouts were analysed by one person (DRD), who is highly competent, qualified and experienced in both boxing and performance analysis.

Attacking movements were recorded detailing whether the movement was made with the lead or rear hand with a straight, hook or uppercut technique, aimed at the head or body of the opponent and if the movement hit (landed within the target area) or missed (hit the opponent but not within the target area). If a punch missed the opponent completely, it was an air punch. Air punches were also recorded as a percentage of missed punches =  $(100/\text{punches missed} \times \text{air punches})$ . Furthermore, an attacking movement was recorded whether it was a single punch or part of a combination. Defensive actions recorded included those with the hand, trunk and foot. Vertical hip movements (VHM) were defined as any visually identifiable vertical activity of the pelvis linked to boxing-specific ambulation. Clinching was defined as time spent hugging the opponent while trapping the arms. Activity rate reported as actions per second included all attacking actions, defensive actions and VHM divided by the net activity time (net activity time = round time – total clinch and referee stoppage time). An index of punching accuracy was calculated via a ratio of punches landed to thrown, as previously described by Davis *et al.*<sup>3-5 7</sup> Injuries and referee interventions were also recorded including: knockout (boxer unable to get up), knockdown (boxer able to get up), technical knockout (boxer unable to defend or injured such as a bleeding skin split) and injuries such as skin splits where the bout continued.

### Data analysis

Results are reported as means  $\pm$  SD and (95% CIs). Values are reported for winners and losers combined. An independent sample t-test was used to detect any differences in technique between the two bout formats. Standardised effect size

(Cohen's *d*) was used to interpret the magnitude of difference between pre-2013 and post-2013 data and was reported where appropriate. A common interpretation of effect sizes is: small ( $d=0.2$ ), medium ( $d=0.5$ ) and large ( $d=0.8$ ) based on the work of Cohen.<sup>16</sup> Five random bouts from each format were analysed twice to check for consistency by comparing the two different results with interclass correlation coefficients (ICC). SPSS V.21 for Windows (IBM) was used for all data analysis.

### RESULTS

Pre-2013, all bouts lasted the full duration ( $3 \times 3$  mins = 9 min). Post-2013, 48 out of 50 bouts (96%) lasted the full duration; one bout (2%) stopped after a boxer was given a standing count followed by a knockdown from a head punch. The other stoppage (2%) was due to a bleeding facial skin split. There were a further seven referee stoppages due to facial skin splits, but these bouts continued. The percentage of rounds where standing counts were issued changed from 9% to 3% pre-2013 to post-2013. However, based on official figures covering all bouts in these two competitions (239 and 238, pre-2013 and post-2013, respectively), pre-2013, 1.7% did not last the full duration as a result of the referee stopping the contest. Post-2013 4.2% did not last the full duration as a result of two knockouts and eight technical knockouts.<sup>17</sup> Pre-2013, the clock was stopped for all referee stoppage, therefore boxers were 'active' for the full round length, resulting in a total round length of  $\sim 200$  s. Post-2013, the clock was only stopped at the referee's request, resulting in the rounds lasting closer to their designated time  $\sim 184$  (s). The ratio of head to body punches pre-2013 was 5:1 increasing to 8:1 post-2013. For the five bouts that were analysed twice from each competition, the mean ICCs was 0.996.

There was a difference pre-2013 to post-2013 in the three main groups of movements in boxing: total punches were lower post-2013 in round (R) 2, total defence was higher post-2013 in R1, R2 and as a bout average, and VHM was higher post-2013 in R1, R2, R3 and as a bout average (table 1). Punch accuracy was negatively affected post-2013, represented by the ratio of landed to thrown punches, which were lower post-2013 in R2, R3 and as a bout average. Further represented by the percentage of missed punches that were air-punches, which were higher in all three rounds and as a bout average (table 1). Total stop time and its constituent parts: clinch frequency, total clinch time and referee stop time were all lower post-2013 in R3 and as a bout average, total stop time was also lower in R1 (table 1). The activity rate was higher post-2013 in all three rounds and as a bout average, and the activity to break ratio was higher post-2013 in R3 (table 1).

Other parameters were measured and checked for differences as absolute values, pre-2013 to post-2013. Parameters that did not change in any of the three rounds or as a bout average are not reported in (table 1), they include: air punches, body-head, lead hand, double punch, triple punch and block and counterpunch combinations, foot defence, amount of time before the first stop, total punches with the lead hand, head punches, missed punches and straight and hook punches with the lead hand (all  $p > 0.05$ ).

As there was a significant difference in total punches thrown (table 1), all other punching variables were reported as a percentage of total punches (table 2). Furthermore, punches that landed on their target were reported as a percentage of all landed punches (table 2). Punches that landed, with the rear hand, to the body, uppercut punches, hooks with the rear-hand and all punches with the rear-hand were all lower post-2013

**Table 1** Comparison of variables reported as absolute values

Parameter	Study	Bout average	Round 1	Round 2	Round 3
Total punches	Pre-2013 (95% CI)	65.2±19.7 (60.0 to 70.4)	61.0±20.5 (55.6 to 66.4)	70.7±23.5 (64.6 to 76.9)	63.8±21.4 (58.1 to 69.5)
	Post-2013 (95% CI)	62.7±19.5 (58.2 to 67.2)	62.3±21.2 (57.5 to 67.0)	62.9±21.2 (58.1 to 67.7)	62.9±21.7 (57.9 to 67.8)
	p=, d	ns	ns	0.048, d=0.35	ns
Total defence	Pre-2013 (95% CI)	8.1±3.8 (7.1 to 9.1)	9.2±4.3 (8.0 to 10.3)	8.0±4.7 (6.8 to 9.3)	7.1±4.7 (5.9 to 8.4)
	Post-2013 (95% CI)	10.8±6.6 (9.3 to 12.3)	12.4±7.3 (10.6 to 13.9)	11.3±7.4 (9.6 to 13.0)	8.7±7.3 (7.0 to 10.3)
	p=, d	0.004, d=0.48	0.002, d=0.50	0.002, d=0.50	ns
Landed: thrown (1:X)	Pre-2013 (95% CI)	7.6±5.9 (6.0 to 9.1)	8.9±9.5 (6.4 to 11.4)	7.3±6.0 (5.6 to 8.9)	6.6±10.6 (3.8 to 9.3)
	Post-2013 (95% CI)	10.0±5.1 (8.9 to 11.2)	9.3±4.8 (8.2 to 10.3)	10.3±7.6 (8.6 to 12.0)	10.5±9.7 (8.3 to 12.7)
	p=, d	0.012, d=0.45	ns	0.012, d=0.43	0.028, d=0.39
Clinch frequency	Pre-2013 (95% CI)	3.5±1.5 (3.1 to 3.9)	2.5±2.0 (2.0 to 3.0)	3.2±2.1 (2.7 to 3.8)	4.8±2.6 (4.1 to 5.4)
	Post-2013 (95% CI)	2.6±1.6 (2.3 to 3.0)	2.0±2.0 (1.5 to 2.4)	2.9±2.1 (2.4 to 3.4)	3.1±1.8 (2.6 to 3.5)
	p=, d	0.002, d=0.55	ns	ns	<0.001, d=0.78
Total clinch time (s)	Pre-2013 (95% CI)	19.5±9.5 (17.0 to 21.0)	12.6±11.0 (9.7 to 15.4)	17.2±12.0 (14.0 to 20.4)	28.7±17.7 (24.0 to 33.3)
	Post-2013 (95% CI)	14.3±8.9 (12.2 to 16.3)	9.2±9.4 (6.8 to 11.1)	16.4±13.3 (13.4 to 19.5)	17.1±10.5 (14.9 to 19.5)
	p=, d	0.002, d=0.57	0.049, d=0.35	ns	<0.001, d=0.82
Referee stop time (s)	Pre-2013 (95% CI)	15.2±10.7 (12.4 to 18.0)	9.0±8.3 (6.8 to 11.2)	15.1±12.9 (6.8 to 11.2)	21.5±18.4 (6.8 to 11.2)
	Post-2013 (95% CI)	11.7±7.3 (10.0 to 13.4)	7.9±8.3 (5.9 to 9.6)	13.4±10.9 (5.9 to 9.6)	13.8±11.0 (5.9 to 9.6)
	p=, d	0.036, d=0.39	ns	ns	0.006, d=0.52
Total stop time (s)	Pre-2013 (95% CI)	34.7±15.8 (30.5 to 38.8)	21.5±15.0 (17.6 to 25.5)	32.3±18.0 (27.6 to 37.1)	50.2±25.0 (43.6 to 56.7)
	Post-2013 (95% CI)	26.0±13.7 (22.8 to 29.1)	17.2±14.2 (13.5 to 19.9)	29.8±17.8 (25.7 to 33.9)	31.0±15.7 (27.3 to 34.5)
	p=, d	0.001, d=0.59	ns	ns	<0.001, d=0.95
Activity rate (s <sup>-1</sup> )	Pre-2013 (95% CI)	1.31±0.24 (1.25 to 1.37)	1.18±0.26 (1.11 to 1.25)	1.34±0.26 (1.27 to 1.41)	1.41±0.29 (1.34 to 1.49)
	Post-2013 (95% CI)	1.55±0.26 (1.49 to 1.61)	1.47±0.26 (1.41 to 1.53)	1.60±0.27 (1.53 to 1.65)	1.60±0.29 (1.53 to 1.65)
	p=, d	<0.001, d=0.97	<0.001, d=1.1	<0.001, d=0.94	0.001, d=0.63
Activity to break ratio (X:1)	Pre-2013 (95% CI)	17.9±22.1 (12.1 to 23.7)	31.2±54.0 (17.0 to 45.4)	16.2±35.0 (6.9 to 25.4)	6.4±4.3 (5.3 to 7.5)
	Post-2013 (95% CI)	19.3±22.7 (14.1 to 24.5)	40.9±60.9 (27.1 to 54.7)	12.6±18.0 (8.4 to 16.7)	8.2±6.0 (6.8 to 9.6)
	p=, d	ns	ns	ns	0.048, d=0.33
Vertical hip movements	Pre-2013 (95% CI)	139.5±28.0 (139 to 147)	131.0±30.0 (123 to 139)	143.0±34.3 (134 to 152)	144.5±28.4 (137 to 152)
	Post-2013 (95% CI)	166.7±26.0 (161 to 173)	167.4±29.2 (162 to 175)	165.6±27.8 (159 to 161)	167.0±29.3 (160 to 174)
	p=, d	<0.001, d=1.0	<0.001, d=1.3	<0.001, d=0.73	<0.001, d=0.78
Air punch as % of miss	Pre-2013 (95% CI)	78.6±12.6 (75.3 to 81.9)	79.7±13.3 (76.1 to 83.1)	78.4±13.9 (74.8 to 82.0)	77.8±13.3 (74.3 to 81.3)
	Post-2013 (95% CI)	86.5±5.0 (85.3 to 87.6)	86.2±7.0 (84.7 to 87.8)	86.8±6.4 (85.4 to 88.2)	86.2±6.9 (84.6 to 87.8)
	p=, d	<0.001, d=0.86	0.001, d=0.64	<0.001, d=0.81	<0.001, d=0.83

All variables are reported as absolute and are a direct comparison between pre-2013 and post-2013 unless otherwise denoted. A value is reported in the p=row where a significant difference ( $p<0.05$ ) exists between pre-2013 and post-2013 data. 'Pre-2013' refers to data from the Davis *et al's* study.<sup>4</sup> 'Post-2013' refers to data from the Davis *et al's* study.<sup>7</sup> The 'Bout Average' column represents the average of that parameter in all three rounds.  $d$ =Cohen's  $d$ ; this represents the effect size and is used to interpret the magnitude of difference between the pre-2013 and post-2013 data; this is reported where a significant difference was found. ns, not significant.

in all three rounds and as a bout average. Hook punches were lower post-2013 in R1, R2 and as a bout average. Air punches were lower in R3 and as a bout average, and punch combinations consisting on four or more punches were also lower post-2013 in R2 (table 2). Punches that missed their target, with the lead hand, to the head and straight lead-hand punches were all higher post-2013 in all three rounds and as a bout average. Straight punches and single punches were both higher post-2013 in R1, R2 and as a bout average. Lastly, straight rear-hand punches that hit their target were higher post-2013 in R3 and as a bout average.

Other parameters were measured and checked for differences either relative to total punches or total landed punches, pre-2013 to post-2013. Parameters that did not change relative to total punches in any of the three rounds or as a bout average are not reported in (table 2), these include: double and triple punch combinations, straight rear-hand and hook lead-hand punches (all  $P >0.05$ ). Parameters that did not change relative to landed punches include: hook lead-hand and rear-hand hit, straight lead hit and body and head punches hit (all  $p >0.05$ ).

## DISCUSSION

To the best of the authors' knowledge, this is the first study to provide a comparison of bout strategy, technique and knock-outs and injuries of elite male amateur boxers before and after the 2013 rules change. The change in rules has had a large effect on both absolute and relative measured parameters. However, whether these changes have been deliberately implemented at the instruction of coaches or whether they are a natural reaction of the boxers due to different in-bout demands is not clear. Boxers are using less 'in-close' punching techniques and more long distance techniques. Movement around the ring has increased 20%, and the boxers are using more defensive movements instead of absorbing punches on their guard, suggesting the new rules have created a sport in which boxers are more concerned about being punched. The frequency of use of many techniques has changed. For example, pre-2013 in R2 both winners and losers managed to throw (~15%) more punches than the in R1 and R2 to try and impose dominance, this is no longer apparent.<sup>4,7</sup>

**Table 2** Comparison of punching-based variables relative to total punches thrown

Parameter	Study	Bout average	Round 1	Round 2	Round 3
Hit %	Pre-2013 (95% CI)	21.5±12.6 (18.2 to 24.8)	20.3±13.3 (16.8 to 23.8)	21.6±13.9 (17.9 to 25.2)	22.2±13.3 (18.7 to 25.7)
	Post-2013 (95% CI)	13.5±5.0 (12.3 to 14.6)	13.8±7.1 (12.1 to 15.4)	13.2±6.4 (11.7 to 14.6)	13.8±6.9 (12.2 to 15.4)
	p=, d	<0.001, d=1.1	<0.001, d=0.76	<0.001, d=0.98	<0.001, d=0.98
Miss %	Pre-2013 (95% CI)	78.5±12.6 (75.2 to 81.8)	79.7±13.3 (76.2 to 83.2)	78.4±13.9 (74.8 to 82.1)	77.8±13.3 (74.3 to 81.3)
	Post-2013 (95% CI)	86.5±5.0 (85.4 to 87.7)	86.2±7.1 (84.6 to 87.8)	86.8±6.4 (85.4 to 88.3)	86.2±6.9 (84.6 to 87.8)
	p=, d	<0.001, d=1.1	<0.001, d=0.76	<0.001, d=0.98	<0.001, d=0.98
Air %	Pre-2013 (95% CI)	24.6±13.1 (21.2 to 28.1)	26.0±16.1 (21.7 to 30.2)	24.4±14.4 (20.7 to 28.2)	24.1±13.3 (20.6 to 27.6)
	Post-2013 (95% CI)	19.5±15.0 (16.1 to 23.0)	21.3±16.8 (17.5 to 25.0)	19.6±16.5 (15.9 to 23.4)	18.9±15.5 (15.4 to 22.5)
	p=, d	0.039, d=0.37	ns	ns	0.040, d=0.36
Lead %	Pre-2013 (95% CI)	55.9±11.5 (52.9 to 58.9)	57.7±13.9 (54.0 to 61.4)	55.4±11.0 (52.5 to 58.3)	54.8±12.6 (51.5 to 58.1)
	Post-2013 (95% CI)	60.8±7.2 (59.2 to 62.5)	62.4±8.6 (60.5 to 64.4)	60.4±8.5 (58.5 to 62.4)	59.9±8.1 (58.1 to 61.8)
	p=, d	0.005, d=0.60	0.025, d=0.49	0.005, d=0.57	0.009, d=0.56
Rear %	Pre-2013 (95% CI)	44.1±11.5 (41.0 to 47.1)	42.3±13.9 (38.6 to 46.0)	44.6±11.0 (41.7 to 47.5)	45.2±12.6 (41.9 to 48.5)
	Post-2013 (95% CI)	39.2±7.2 (37.5 to 40.8)	37.6±8.6 (35.6 to 39.5)	39.6±8.5 (37.6 to 41.5)	40.1±8.1 (38.2 to 41.9)
	p=, d	0.005, d=0.60	0.025, d=0.49	0.005, d=0.57	0.009, d=0.56
Head %	Pre-2013 (95% CI)	83.0±11.2 (80.1 to 85.9)	82.8±11.7 (79.7 to 85.8)	82.9±12.2 (79.7 to 86.1)	83.7±12.3 (80.4 to 86.9)
	Post-2013 (95% CI)	89.1±6.4 (87.7 to 90.6)	87.7±8.3 (85.8 to 89.6)	89.2±7.5 (87.5 to 90.9)	90.1±8.2 (88.1 to 92.0)
	p=, d	<0.001, d=0.81	0.007, d=0.56	0.001, d=0.73	0.001, d=0.71
Body %	Pre-2013 (95% CI)	17.0±11.2 (14.1 to 19.9)	17.2±11.7 (14.2 to 20.3)	17.1±12.2 (13.9 to 20.3)	16.3±12.3 (13.1 to 19.6)
	Post-2013 (95% CI)	10.9±6.3 (9.4 to 12.3)	12.3±8.3 (10.4 to 14.2)	10.8±7.5 (9.1 to 12.5)	9.9±8.2 (8.1 to 11.8)
	p=, d	<0.001, d=0.81	0.007, d=0.56	0.001, d=0.73	0.001, d=0.71
Straight %	Pre-2013 (95% CI)	51.3±17.2 (46.8 to 55.9)	51.8±18.9 (46.8 to 56.8)	50.0±18.3 (45.2 to 54.8)	52.8±18.4 (48.0 to 57.7)
	Post-2013 (95% CI)	59.6±15.4 (56.0 to 63.0)	62.8±16.5 (59.0 to 66.5)	58.6±17.4 (54.7 to 62.5)	58.1±16.4 (54.3 to 61.8)
	p=, d	0.005, d=0.53	0.001, d=0.66	0.006, d=0.51	ns
Hook %	Pre-2013 (95% CI)	42.5±15.7 (38.3 to 46.6)	43.0±17.1 (38.5 to 47.5)	43.5±16.4 (39.2 to 47.8)	40.8±17.4 (36.2 to 45.4)
	Post-2013 (95% CI)	37.0±14.7 (33.6 to 40.3)	34.7±15.9 (31.1 to 38.2)	37.5±16.5 (33.7 to 41.2)	37.9±15.5 (34.3 to 41.4)
	p=, d	0.042, d=0.38	0.005, d=0.53	0.038, d=0.38	ns
Uppercut %	Pre-2013 (95% CI)	6.2±6.0 (4.6 to 7.8)	5.2±7.4 (3.3 to 7.2)	6.5±6.8 (4.7 to 8.3)	6.4±6.8 (4.6 to 8.2)
	Post-2013 (95% CI)	3.5±3.7 (2.7 to 4.4)	2.6±3.4 (1.8 to 3.4)	3.9±5.0 (2.7 to 5.0)	4.1±4.7 (3.0 to 5.2)
	p=, d	0.004, d=0.63	0.014, d=0.58	0.015, d=0.50	0.027, d=0.46
Straight lead %	Pre-2013 (95% CI)	30.3±15.1 (29.9 to 30.4)	31.8±17.5 (27.2 to 36.4)	29.4±14.9 (25.5 to 33.3)	30.0±15.5 (26.0 to 34.1)
	Post-2013 (95% CI)	37.0±13.0 (34.1 to 40.0)	39.9±14.3 (36.6 to 43.1)	36.2±14.8 (32.8 to 39.6)	35.6±13.7 (32.5 to 38.7)
	p=, d	0.008, d=0.51	0.005, d=0.55	0.010, d=0.48	0.032, d=0.41
Hook rear %	Pre-2013 (95% CI)	18.8±9.3 (16.4 to 21.3)	18.7±10.0 (16.0 to 21.3)	19.5±10.7 (16.7 to 22.3)	18.1±10.3 (15.4 to 20.8)
	Post-2013 (95% CI)	14.1±8.6 (12.2 to 16.1)	13.0±8.7 (11.1 to 15.0)	14.1±10.3 (11.7 to 16.4)	14.7±9.4 (12.5 to 16.8)
	p=, d	0.004, d=0.55	0.001, d=0.65	0.004, d=0.54	0.039, d=0.37
Single punch %	Pre-2013 (95% CI)	29.2±11.4 (26.6 to 32.2)	31.0±12.9 (27.6 to 34.4)	27.7±12.5 (24.5 to 31.0)	30.0±14.1 (26.7 to 33.7)
	Post-2013 (95% CI)	33.8±11.7 (31.1 to 36.5)	36.7±14.7 (33.3 to 40.0)	33.8±14.6 (30.4 to 37.1)	32.8±14.4 (29.5 to 36.1)
	p=, d	0.023, d=0.41	0.019, d=0.42	0.011, d=0.45	ns
Combination 4+	Pre-2013 (95% CI)	3.4±2.2 (2.9 to 4.0)	3.3±2.6 (2.7 to 4.0)	3.6±2.7 (2.9/4.3)	3.1±2.7 (2.4 to 3.8)
	Post-2013 (95% CI)	2.7±2.3 (2.2 to 3.3)	2.5±2.6 (1.9 to 3.1)	2.4±2.5 (1.9/3.0)	3.1±3.0 (2.4 to 3.8)
	p=, d	ns	ns	0.011, d=0.48	ns
Straight rear hit %	Pre-2013 (95% CI)	22.8±10.6 (20.0 to 25.6)	23.4±22.5 (17.5 to 29.3)	23.7±14.5 (19.8 to 27.5)	22.1±16.6 (17.8 to 26.5)
	Post-2013 (95% CI)	28.0±12.3 (25.2 to 30.8)	27.8±22.1 (22.8 to 32.8)	27.7±25.3 (22.0 to 33.5)	29.0±20.7 (24.3 to 33.7)
	p=, d	0.01, d=0.46	ns	ns	0.035, d=0.37

All variables are reported as absolute and are a direct comparison between pre-2013 and post-2013, unless otherwise denoted. A value is reported in the p= row, where a significant difference ( $p < 0.05$ ) exists between pre-2013 and post-2013 data. 'Pre-2013' refers to data from the Davis *et al's* study.<sup>4</sup> 'Post-2013' refers to data from the Davis *et al's* study.<sup>7</sup> The 'Bout Average' column represents the average of that parameter in all three rounds.  $d$ =Cohen's  $d$ ; this represents the effect size and is used to interpret the magnitude of difference between the pre-2013 and post-2013 data; this is reported where a significant difference was found. ns, not significant.

The ability to increase the accuracy of punches over subsequent rounds was a factor that leads to winning pre-2013, highlighted by the increase in the punches landed to thrown. The change in the ratio of punches landed to thrown effectively means that boxers must now throw ~30% more punches to land the same amount as pre-2013. This possibly reflects the higher amount of deliberate defensive movements, the difficulty in land

punches while not boxing in-close or the fact that removal of head guards has resulted in a smaller and therefore harder target to hit. Pre-2013, there were less defensive movements used by winners compared with losers; this is no longer apparent post-2013. Boxers tended to absorb punches on their guard instead of making deliberate defensive movements.<sup>4</sup> Post-2013 has resulted in a higher amount of total defensive movements. It is suggested

that this increase is a result of boxers' concerns of punches slipping through their guard resulting in a knockout. Therefore, deliberate defensive actions are being used to reduce the risk of head shots finding their target.<sup>4,7</sup> The post-2013 increase in VHM, single punches, straight lead hand punches, lead punches and straight punches, combined with the decrease of hook punches, rear hand punches, rear hand hooks, uppercuts and combinations consisting of four or more punches highlights that the sport has become much more about stepping-in, throwing a single punch and moving back away to a safe distance. This new style has had an effect on punch accuracy; air punches as a percentage of missed punches and punches that missed are both higher, and the number of landed punches and the ratio of punches landed to thrown are lower post-2013.<sup>4,7</sup>

Pre-2013 the clock was stopped whenever the referee was, for example, talking to the boxers or breaking the boxers apart from a clinch. This resulted in rounds lasting ~20 s (11%) longer than their intended time.<sup>4</sup> Post-2013 the clock is stopped only at the referee's request; this resulted in only 19 clock stoppages out of 50 bouts, resulting in the rounds lasting much closer to their designated time ~184 s.<sup>7</sup>

The data from the current study are concerned with the difference between the pre-2013 and post-2013 format. Previous data have been published, individually looking at the difference in parameters over subsequent rounds.<sup>4,7</sup> Pre-2013 there was a pronounced inverted U-shape to the attacking movements over subsequent rounds. Total punches landed, hook lead-hand punches and straight punches increased from R1 to R2, and punches to the head, hook punches, hook punches with the rear-hand and punches per minute increased from R1 to R2 and subsequently decrease from R2 to R3.<sup>4</sup> With regards to the mainly time-based parameters such as total stop time and frequency, referee stop time and frequency, total clinch time and frequency, time before first stop and the activity to break ratio, they all increase from R1 to R2 and stayed at the same level for R3.<sup>4</sup> The rule change in 2013 had a significant effect; the amount of all attacking movements was consistent over subsequent rounds, and only defensive movements change, with a decrease from R1 to R3. The mainly time-based parameters also changed, with the majority increasing from R1 to R2, R1 to R3 and R2 to R3.<sup>7</sup>

Due to a lack of evidence of their benefit<sup>18,19</sup> and evidence to the contrary,<sup>10</sup> it was deemed acceptable and possibly beneficial by AIBA to remove head guards in the 2013 rules change.<sup>20</sup> Possibly surprising to some, the effect this has had, is a reduction in standing counts. The percentage of rounds where standing counts were issued changed from 9% pre-2013 to ~3% post-2013.<sup>4,7</sup> However, this finding is similar to results reported from World Series Boxing (WSB).<sup>10</sup> This is a global team boxing competition that competes in a league format. It is similar to Olympic boxing in the sense that it uses the 10-point must scoring system, adheres to the same AIBA weight categories and does not allow head guards. However, WSB acts to bridge the gap between the amateur and professional variants of the sport, therefore boxers compete without vests and bouts consist of 5×3 min rounds. These results appear to suggest a reduction in punches to the head that the referee deemed forceful enough that the boxer needed time to recover and be assessed for injury. However, due to the alignment of amateur with professional boxing and the influence of WSB, an alternate explanation or combined influencing factor could be: referees in amateur boxing are using a more 'professional' style of refereeing. Thus, abstaining from intervening in the competition and allowing the boxers to compete more freely in the way they choose.

However, knockdowns due to a head punch and skin splits resulting in the referee stopping the bout were both higher post-2013,<sup>7</sup> with one incident of each (4%), while pre-2013, there were none. Based on official figures of all bouts in these two competitions, pre-2013, 1.7% of bouts did not last the full duration due to the referee stopping the contest, while post-2013, 4.2% did not last the full duration due to two knockouts and eight technical knockouts.<sup>17</sup> However, without access to the complete data and information on severity and reasons for referee stoppages and knockouts, it is difficult to make an accurate comparison or come to a conclusion. It is also not possible to know whether any of the knockouts or technical knockouts resulted in concussive or traumatic brain injuries. Furthermore, this leads to the question: what is safer for the boxers? One or two punches to the head without a head guard will ultimately result in the referee ending the bout due to a knockout or technical knockout, or repeated impacts with a possibly dissipated force from a head guard resulting in the referee giving a standing count and then letting the boxer continue to sustain further head punches. This is an interesting question and one that warrants further research.

Part of the reason for the 2013 rules change was to align amateur with professional boxing so that the athletes can transition more easily. However, in 50 bouts, there were eight referee stoppages due to blood and a bout was ended due to the severity of a head cut compared with zero blood events pre-2013.<sup>4,7</sup> This result suggests an unbeneficial effect of removing head guards, especially those looking to make a career in professional boxing. It is well known that once the skin has been split and scarred, it is weakened, resulting in a higher risk in future bouts of a punch opening an old wound ending a bout prematurely.<sup>21,22</sup> Punches to the body have always been lower than those to the head; a common reason given is that judges are unlikely to score punches to the body whether they land or not. Pre-2013 the ratio of head to body punches was 5:1, while post-2013 it is 8:1, possibly reflecting the boxers' belief that removing the head guard means greater trauma can be caused to the head resulting in a knockout.<sup>4,7</sup> However, based on the current study and previously published studies, it seems unlikely that the 2013 change in rules have changed the fact that amateur boxing is a safe sport with very little risk of serious health consequences.<sup>10,14,18,23,24</sup> Although, our data show that technical knockouts and injuries such as skin splits are higher.

The authors acknowledge that the repeat analysis of a boxer in more than one bout, due to the elimination nature of the competition, is a limitation to the study. We accept that this could have skewed some of the data by over-representation of an individual boxer's technique and tactics. However, it is believed that when faced with a different opponent, a boxer will adapt and change their technique and tactics to match. Furthermore, as many differences in the data pre-2013 to post-2013 were highly significant ( $p < 0.001$  or close), we do not believe that this possible small skew would have significantly changed the results.

## CONCLUSION

The present study is the first to provide an in-depth comparison of amateur boxing, before and after the 2013 rules change. In just over 2 years since the rules were altered, there have been a large amount of changes within the sport. Nearly all of the techniques that were dominant pre-2013 have reduced in use. Pre-2013 boxing was a sport where boxers would stay in-close using short-range technique while taking incoming punches on their guard. Post-2013 boxing is now composed of boxers increasing their

foot movement to move in and away from the opponent, using long-range punching techniques and using deliberate defensive movements to make sure punches do not land. It is considered likely that this is due to the boxers' concerns that head guard removal has made them more vulnerable to knockouts. This concern seems valid as the ratio of head-to-body punches has increased from 5:1 to 8:1 post-2013.

Whether the new rules and subsequent changes in bout strategy and technique have resulted in an increase of concussive or traumatic brain injury is unclear, further research is needed in this area to fully understand the effect, if any. Whether it is better to be punched once and knocked down and the bout ends, or whether it is better to be hit with a head guard on, given a standing count and then continue to sustain further head punches is equivocal. However, what is certain is that boxers and possibly more importantly their coaches and corner team should be aware of the increased risk of technical knockouts and facial skin splits. The team should adapt techniques to reduce the risk of head clashes, use methods to help punches slide off their boxers' face and be aware of appropriate methods to improve the healing process of such injuries, both in the ring and postbout.

#### What are the findings?

- ▶ Within 2 years of rule changes nearly all techniques that were dominant pre-2013 have significantly reduced in use.
- ▶ It is unclear whether the change in rules has had an effect on the amount of concussive and traumatic brain injuries.
- ▶ The change in rules has increased the risk of skin splits. Boxers' and their support teams need to be aware of this, adapt techniques to reduce the risk and be aware of how to treat skin splits, both during and after the bout.

#### How might it impact on clinical practice in the future?

- ▶ Ringside physicians should be prepared to deal with skin splits at a higher frequency than previously.
- ▶ Modules should be introduced and updated on the Amateur International Boxing Association coaching courses, giving information on how to deal with skin splits and cuts in the ring and aid healing postbout.

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